19 OCT 1937

ICAR. 7
2000

Report on the work of the Imperial Council of Agricultural Research in applying science to Crop Production in India

BY

Sir JOHN RUSSELL, D. Sc., F. R. S.

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI.
PRINTED BY THE MANAGER, GOVERNMENT OF INDIA PRESS, SIMLA.
1937
Price : Rs. 1-14-0 or 3s. 3d.

List of Agents in India from whom Government of India Publications are available.

(a) PROVINCIAL GOVERNMENT BOOK DEPOTS.

MADRAS :—Superintendent, Government Press, Mount Road, Madras.

BOMBAY :—Superintendent, Government Printing and Stationery, Queen's Road, Bombay.

SIND :—Manager, Sind Government Book Depot and Record Office, Karachi (Sadar).

UNITED PROVINCES :—Superintendent, Government Press, Allahabad.

PUNJAB :—Superintendent, Government Printing, Punjab, Lahore. — 39,958 —

CENTRAL PROVINCES :—Superintendent, Government Printing, Central Provinces, Nagpur.

ASSAM :—Superintendent, Assam Secretariat Press, Shillong.

BIHAR :—Superintendent, Government Printing, P. O. Gulzarbagh, Patna.

NORTH-WEST FRONTIER PROVINCE :—Manager, Government Printing and Stationery, Peshawar.

ORISSA :—Press Officer, Secretariat, Cuttagk.

(b) PRIVATE BOOKSELLERS.

Advani Bros., P. O. Box 100, Cawnpore.
Aero Stores, Karachi *.
Banthiya & Co., Ltd., Station Road, Ajmer.
Bengal Flying Club, Dum Dum Cantt.*
Bhawnani & Sons, New Delhi.
Bhatia Book Depot, Sadar Bazar, Ranikhett.
Book Company, Calcutta.
Booklover's Resort, Taikad, Trivandrum, South India.
Burma Book *Club*, *Ltd.*, Rangoon.
Butterworth & Co. (India), Ltd., Calcutta.
Chatterjee & Co., 3, Bacharam Chatterjee Lane, Calcutta.
Chukervertty, Chatterjee & Co., Ltd., 15, College Square, Calcutta.
City Book Club, 98, Phayre Street, Rangoon.
Das Gupta & Co., 54/3, College Street, Calcutta.
Delhi and U. P. *Flying* Club, Ltd., Delhi.*
English Book Depot, Ferozepore.
English Book Depot, Taj Road, Agra.
English Bookstall, Karachi.
English Book Store, Abbottabad, N. W. F. P.
Fakir Chand Marwah, Peshawar Cantt.
Fono Book Agency, Simla.
Gautama Brothers & Co., Ltd., Meston Road, Cawnpore.
Higginbothams, Madras.
Hindu Library, 137/F, Balaram De Street, Calcutta.
Hyderabad Book Depot, Chaderghat, Hyderabad (Deccan).
Imperial Book Depot and Press, near Jama Masjid (*Machhliwalan*), *Delhi*.
Indian Army Book Depot, Dayalbagh, Agra.
Indian Book Shop, Benares City.
Indian School Supply Depot, Central Avenue, South, P. O. Dharamtola, Calcutta.
Insurance Publicity Co., Ltd., Lahore.
International Book Service, Poona 4.
Jacques & Co., Kamptee Road, Nagpur, Messrs. Neston.
Jaina & Bros., Mori Gate, Delhi, and Connaught Place, New Delhi, Messrs. J. M.
Kamala Book Depot, 15, College Square, Calcutta.
Karnataka Publishing House, Bangalore City.
Keale & Co., Karachi.
Keshao Book Stall, Khadi Bazar, Belgaum.
Kitabistan, 17-A, City Road, Allahabad.
Krishnaswami & Co., Teppakulam P. O., Trichinopoly *Fort*, Messrs. S.
Lahiri & Co. Calcutta. Messrs. S. K.
Local Self-Govt. Institute, Bombay.
London Book Co. (India), Arbab Road, Peshawar, Murree, Nowshera, Rawalpindi.
Malik & Sons, Sialkot City.
Mathur, B. S., Bookseller, Civil Lines, Jodhpur.
Messrs. The London Book House, 17, Rajpur Road, Dehra Dun.
Messrs. U. P. Malhotra & Co., Post Box No. 94, Lahore.
Minerva Book Shop, Anarkali Street, Lahore.
Modern Book Depot, *Bazar* Road, Sialkot Cantonment.
Modern Book Depot, Napier Road, Jullundur Cantt., and Careers, Mohini Road, Lahore.
Mohanlal Dossabhai Shah, Rajkot.
Nandkishore & Bros., Chowk, Benares City.
New Book Co., " Kitab Mahal ", 192, Hornby Road, Bombay.
Newman & Co., *Ltd.*, *Calcutta*, Messrs. W.
Oxford Book and Stationery Company, Delhi, Lahore, Simla, Meerut and Calcutta.
Parikh & Co., Baroda, Messrs. B.
Pioneer Book Supply Co., 20, Shib Narayan Das Lane, Calcutta, and 219, Cloth Market, Delhi.
Popular Book Depot, Grant Road, Bombay.
Punjab Religious Book Society, Lahore.
Raghunath Prasad & Sons, Patna City.
Rama Krishna & Sons, Booksellers, Anarkali, Lahore.
Ram Krishna Bros., Opposite Bishrambag, Poona City.
Ram Narain Lal, Katra, Allahabad.
Ramesh Book Depot & Stationery Mart, Kashmere Gate, Delhi.
Ray & Sons, 43, K. & L. Edwardes Road, Rawalpindi, Murree and Peshawar, Messrs. J.
Roy Chowdhury & Co., 72, Harrison Road, Calcutta, Messrs. N. M.
Sharada Mandir, Ltd., Nai Sarak, Delhi.
Saraswati Book Depot, 25, Lady Hardinge Road, New Delhi.
Sarcar & Sons, 15, *College Square, Calcutta*, Messrs. M. C.
Sarkar & Co., Ltd., 6, Hastings Street, and 8/2 Hastings Street, Calcutta, Messrs. P. C.
Standard Bookstall, Karachi.
Standard Bookstall, Quetta.
Standard Book Depot, Lahore, *Dalhousie* and *Delhi*.
Standard Law Book Society, 69, Harrison Road, Calcutta
Tara & Sons, Razmak (India), Messrs. B. S.
Taraporevala Sons & Co., Bombay, Messrs. D. B.
Thacker & Co., Ltd., Bombay.
Thacker, Spink & Co., Ltd., Calcutta and Simla.
Tripathi & Co., Booksellers, Princes Street, Kalbadevi Road, Bombay, Messrs. N. M.
University Book Agency, Kacheri Road, Lahore.
Upper India Publishing House, Ltd., Literature Palace, Ammuddaula Park, Lucknow.
Varadachary & Co., Madras, Messrs. P.
Venkatasubban, A., Law Bookseller, Vellore.
Wheeler & Co., Allahabad, Calcutta and Bombay, Messrs. A. H.
Young Man & Co., Egerton Road, Delhi.

*Agent for publications on Aviation only.

To

The Honourable The Chairman of the Imperial Council of Agricultural Research,
New Delhi.

Sir,

Herewith I beg to transmit my Report on the work of the Imperial Council of Agricultural Research in promoting investigations on the science and practice of crop production in India.

The Report is in two parts.

In the First Part I have brought together the general results obtained, and discussed them in relation to the difficult problems associated with the improvement of agriculture and the raising of the standard of life for the cultivator.

In the Second Part I have dealt with the individual schemes fostered by the Council, and set out various recommendations. This part is necessarily somewhat detailed, but I have endeavoured to keep it within manageable limits. During my visit to the Stations I discussed each man's work at length with him and made numerous recommendations on points of detail or of experimental technique which are not included in this Report. Here I have confined myself to those recommendations which the Council alone could implement, should they approve of them.

This method of presenting the Report in two parts involves a certain amount of repetition, but it will, I hope, be found quite convenient in use.

I wish to record my thanks to all those who helped me in the course of my enquiries : especially to His Excellency the Viceroy, who set out the problem with characteristic lucidity and discussed possible solutions with great penetration and insight. I owe much also to the Honourable Sir Jagdish Prasad for several important discussions which proved most helpful in clearing up some of the difficulties I had met during my work ; much also to those Governors, Ministers and Commissioners who received me on my journey and gave me the benefit of their knowledge and wide experience of their Provinces. I have to thank also Mr. N. C. Mehta and the Staffs of the Secretariat, of the Agricultural Departments, Colleges and Experiment Stations, for dealing with my numerous enquiries and furnishing information which often took some time to collect. Particularly I wish to thank Sir Bryce Burt and Dr. Burns for much help ungrudgingly given on innumerable occasions and for placing unreservedly at my disposal their extensive knowledge of Indian agriculture. I am much indebted also to the " Review of the work on Crops and Soils "—the " Brief "—prepared at the Secretariat, which proved most helpful both on the journey and during the preparation of the Report. Since my return to England I have received much useful help in regard to statistical matters from Mr. E. J. Turner of the India Office.

CONTENTS

Report on the work of the Imperial Council of Agricultural Research in applying science to crop production in India.

PART I.

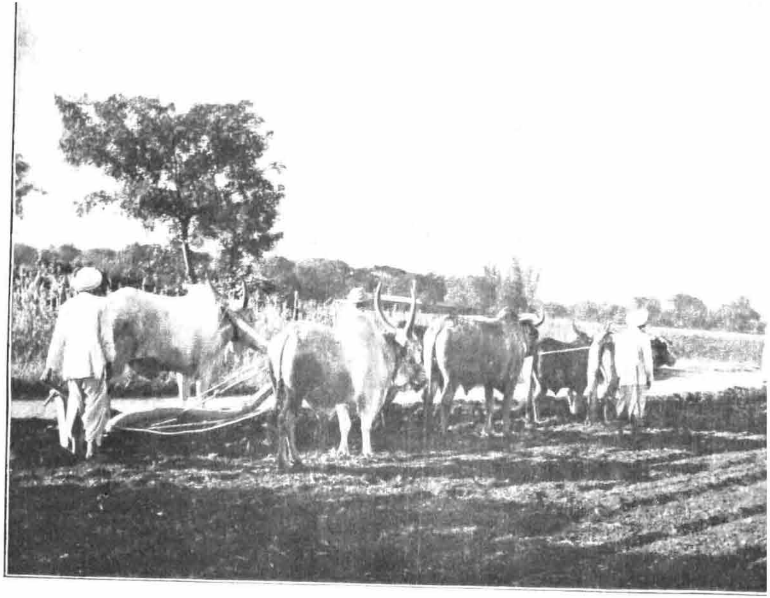
	Page.
Introduction	1
Chapter 1.—The stages in agricultural improvement	3
Chapter 2.—The crops	7
Chapter 3.—Factors improving the yields of crops	46
Chapter 4.—Special difficulties confronting Indian agriculture ..	60
Chapter 5.—The machinery for dealing with these problems ..	70
Chapter 6.—The Imperial Research Institute, New Delhi ..	47

PART II.

The Council's Schemes.

Work directly carried out by the Council	87
Imperial Institute of Agricultural Research, New Delhi	90
Karnal	95
Agra	98
United Provinces	101
The Punjab	120
Sind	135
Baluchistan	144
North-West Frontier Province	144
Simla and Dehra Dun	147
Mungpoo	149
Assam	150
Bengal	155
Bihar	166
Orissa	171
Central Provinces	173
Indore	175
Bombay Presidency	178
Hyderabad	193
Mysore	194
Madras	198
Travancore	214
Summary and Recommendations	215
Appendix.—List of schemes visited and reported upon	227

PART I.



The old wooden plough in Poona.

REPORT ON THE WORK OF THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH IN APPLYING SCIENCE TO CROP PRODUCTION IN INDIA.

Introduction.

The improvement of Indian agriculture has been attempted by many Governments over a long period of years and by a variety of methods. In the first instance Western methods were introduced on the assumption that as they had succeeded in the countries of their origin they would also succeed in India. Notable examples were the bringing in of twelve American cotton planters by the East India Company in 1839 to show how cotton should be grown, and the importation of steam ploughs and a battery of implements by the Madras Government in 1864 to show how the soil should be cultivated. In general these methods failed. Next followed a period of searching for some general policy or system of organisation: little was actually accomplished, but there was much discussion which no doubt paved the way for future action. Finally it was recognised that Indian agriculture constituted a problem of its own; it could not be modelled on any other system but must be developed to accord with the natural conditions of the country and the requirements of its people. The best hope for improvement lay in the scientific study of these conditions and in experiments to discover agricultural practices that would best suit them.

This conclusion was reached only slowly and as the result of pressure of events rather than of deliberate planning. The Famine Commission of 1880, set up to find some practicable means of avoiding famines or at least of mitigating their worst effects, was the first body seriously to study possible methods of improvement. Definite action began a few years later: in 1889 Dr. Voelcker was invited to India to advise on the steps to be taken; in 1892 Mr. James Mollison was appointed as Technical Deputy Director of Agriculture for the Bombay Presidency and began making field experiments; Dr. J. W. Leather came out as agricultural chemist to the Government of India, for the improvement of agriculture was then regarded as a matter more for chemistry than for any other science. Meanwhile, however, pressure of another kind was being exerted: sugar cane diseases were causing much loss to cultivators in Madras and in 1898 Dr. Barber was brought from the West Indies to Madras to deal with them; by a stroke of genius he adopted the idea of selecting or producing disease-resistant varieties and achieved such remarkable success that the whole current of Indian agricultural science set for many years in the direction of plant breeding or genetics. These various activities showed that definite advancement could be achieved on scientific lines and when in 1901 another Famine Commission had to be set up, it had more definite grounds than its predecessors for insisting on the necessity for the establishment of properly organised agricultural departments in the Provinces capable of applying scientific methods to the improvement of agriculture, and, as the principle had by this time been widely accepted elsewhere, it is not surprising that Lord Curzon's Government speedily took action on the Report.

The reorganisations that followed included the strengthening of the Departments on the experimental and scientific sides, the establishment of Agricultural Colleges, of the Central Research Station at Pusa, and other organisations for the purpose of providing sound information about Indian soils, crops and animals on the basis of which the Departments might find solutions of the problems confronting them. The position was made more definite by the Government of India Act of 1919 which put upon the Provincial Departments the main responsibility for agricultural development but reserved to the Central Government the right to promote research by means of Central Institutes and other agencies, and gave also to the Central Government the power to deal with animal and plant diseases.

Then came the Royal Commission on Agriculture in India of 1926 which may fairly be said to have inaugurated a new era in the life of the Indian countryside. The Commission recognised clearly that the problem of improving Indian agriculture was really the problem of improving Indian village life, and that this must be studied as a whole. Its far-reaching conclusions, set out in its Report in 1928—the most comprehensive account of Indian agriculture yet published—have not been allowed to remain in abeyance. Reports are issued periodically showing "the progress made in giving effect to the recommendations of the Royal Commission." More important still, the chairman of the Commission has become the Viceroy with the declared intention of ameliorating the lot of the present, a policy, which as I found everywhere in my journeys, is warmly appreciated in the villages.

The conditions are thus extremely favourable for the application of science to the problems of Indian agriculture. The Provincial Departments have already achieved valuable results and have fully justified the confidence reposed in them from the outset. But science knows no boundaries; its pursuit is costly both in time and in money ; and the more highly it is developed the greater becomes the need for co-ordination. The Royal Commission foresaw this necessity and set up an Imperial Council of Agricultural Research, whose duty it is to give the lead and to co-ordinate wherever this is necessary but not to intervene in Departmental affairs. It derives its authority from its personnel, from the fact that it makes grants for approved investigations, and from its record of successful achievement.

One of the conditions laid down was that the Council's activities should periodically be reviewed by some disinterested expert and the honour of being the first to do this has fallen to my colleague, Dr. N. C. Wright, who is dealing with Animal Husbandry, and myself.

CHAPTER 1.

The Stages in Agricultural Improvement.

The purpose of agriculture is to obtain food and raw products by the cultivation of land, and its distinctive feature is that the process can go on indefinitely without deterioration, in contra-distinction to the exploitation of mineral resources which is possible only once. The agricultural scientific services are set up with the double purpose of educating the cultivator so that he may better understand the natural forces with which he is dealing, and of increasing his means of attacking the serious problems with which he is confronted.

The system of agriculture followed in large parts of India is very ancient, and was formerly very wide spread : it is fundamentally the same as that followed for centuries in England—indeed almost until our own time. It is based on the production of grain for human food, fibre for clothing and oil for burning, but it makes little provision for animal food except the straw or stalks of the grain crop and such wild vegetation as may be available for grazing. In the east, as in olden time in the west, the source of power is the bullock, which, therefore has to be given the first choice when fodder is scarce ; the supply of milk and of meat is consequently limited. The system has two great advantages : permanence, for apart from actual removal of the soil by flood or other agency there is no reason why the system should ever fail, and economy. Some eleven persons are sustained per ten acres of land while on the modern western standards and systems more than double this area is needed. But against this are the grave disadvantages that the yields are low, consequently the villages remain poor ; and the standard of living is low ; the diet provided is almost entirely grain, it lacks variety and is poor in animal products.

The change from the ancient to the modern system took some 70 years to accomplish in the west.

There is no occasion to despair of its accomplishment in India.

The Indian ryot compares favourably with any of the peasant populations I have met in different parts of the world. I visited many Indian villages and spoke with numbers of the inhabitants both in their cottages and on their holdings. It is no mere form of words, but a fact, that the wealth of India lies in the villages. Repeatedly in my journeys I came across men and women doing good, useful work in the towns or the Colleges, and on enquiring their origin found that they had come from villages or were only one generation away. "In the keeping of village", as Tagore reminds us, "lies the cradle of the race".

The improvement of village life is probably the greatest need in India to-day. In this first part of the Report I deal with the ways in which science has helped and can still further help in this work, with special reference to the activities of the Imperial Council for Agricultural Research. Later on I shall refer to some of the difficulties in the way.

There are three stages in the application of science to the problems of village life. In the first instance the science must be well founded: the facts and principles must be clearly proved and their consequences well thought out. This work is never-ending: each generation seeks its own proofs and soon discovers that the supposed facts and principles of its predecessors are only partly true. Further work is done, more discoveries are made and new principles enunciated, only to be displaced in their turn. Scientific investigation consists in making successive approximations to a Truth that can never be attained by human beings.

But there is always a great deal in Science that is sufficiently nearly established to be useful to men and women in their ordinary daily labours, and much work is done in trying to find practicable means of applying the results of science to the problems of village life. This requires a different type of mind from that of the discoverer, and only rarely is the purely scientific investigator capable of doing it effectively: frequently he has no desire whatsoever to do it. The story of the professor, who at the end of a long intellectual career thanked Heaven he had never done anything useful may be apocryphal, but it embodies a great truth. There is no advantage in attempting to fuse scientific discovery with scientific exploitation: separate staffs and separate organisations are needed.

When the application has been worked out the cultivator still has to be persuaded to adopt it. This often takes a long time and the cultivator is abused as slow and conservative because he does not change his methods more rapidly. But it is frequently impossible for him to do this. His unit of time is a year; "Safety First" must always be his guiding principle, and methods known to give subsistence to himself and his family cannot possibly be discarded until the superiority and practicability of the new ones are established beyond question. Even when he is convinced of their advantage he may still lack the means for adopting them. Further, he thinks in terms of his entire system of cultivation and an isolated process, though good in itself, may not fit well in with his general management. This extension work, therefore, requires something more than education and propaganda for the new methods, it involves much adjustment of the new methods to the actual conditions and systems on the cultivators' land.

The first stage—the gaining of knowledge.

This is so distinct from the other two that there is no advantage in trying to combine them. It is best done by men for whom the search is itself the end and the reward, and who are surrounded by young helpers animated by the same spirit. A few can have their own Institutes, but in the main the Universities are the places for the work. The Council has recognised this and has made grants for investigations of purely scientific interest but of some agricultural bearing. This limitation is in my view unnecessary: the scope of the grant should be widened to include all subjects fundamental to the science or practice of agriculture, provided always that the Council is satisfied as to the quality of the research work done in the laboratory concerned and that the subject proposed for

a grant is the major study of the workers there. The ability to make scientific discoveries is just as personal a matter as the ability to paint a great picture or to compose a great poem : it is quite as rare a gift, and while it may be fostered it cannot be created. The best help that could be given to the experiment stations would be to ensure that some of the staff had had a period of serious training in a laboratory where really good scientific work was being done, no matter on what subject. The vitally important thing is the training, and for this it is the man and not the subject that counts.

Science is advancing all over the world, and it is certain that the knowledge required for agricultural improvement will be obtained somewhere and will be announced to all who are interested : the great need in India is the better training of men. The advantage of removing the present limitation would be to bring into the scheme some of the best of the Indian laboratories, which at present take no part, such as those of Professor Sir Venkata Raman, Meghanad N. Saha, Birbal Sahni and others where the scientific work is of a high standard such as would bear comparison with any of the laboratories of the West. A student taking part in some good work in one of these laboratories would imbibe the true research spirit and incidently would learn to avoid the common but very serious faults of diffuseness of programme, uncritical acceptance of methods and conclusions, and fragmentation of publications.

I recommend, therefore, that the Council should allocate a definite sum annually for grants to the Universities to be used for the appointment of research assistants to men actively engaged in scientific research, and that there be no limitation to subjects of agricultural bearing as at present. Any of the assistants who proved successful could if they wished be absorbed in the service, but even if they were not the Council would still have the satisfaction of knowing that it had contributed to the development of research schools in India.

The second stage—the Agricultural Experiment Stations.

The purpose of the experiment station is to apply the methods and results of science to the present day problems of the cultivator. Responsibility to the present generation must be recognised : refuge should not be taken in the pious hope that practical results may somehow and some day emerge from the work. This is widely recognised in the Stations I visited and the programmes were in general on useful lines though they were often too ambitious. Three weaknesses are fairly common. The work is frequently too diffuse—a fault not confined to experiment stations : when this happens the results lack definiteness. In many cases the work is confined too much to the laboratory and the pot culture house : the field and the growing crop should be the centre. Almost always it is restricted to the experiment station : test experiments should be carried out on other soils and at other centres not too far removed, so as to ensure that all factors coming into play are recognised.

In view of the fact that Indian experiment stations have been functioning for so many years it seems at first surprising that so little of the work done has found its way into the general body of

agricultural science as expounded in the standard treaties. It is comparatively rare to find references to Indian investigations in books published outside India. Probably the chief reason is the widespread Indian practice of publishing the results in a large number of small communications, many of which are uncritical and unimportant having the character rather of journalism than of serious scientific literature. Research demands that a man should think long and carefully about it ; hurried and scrappy publication prevents him doing this. It would undoubtedly enhance the dignity and reputation of Indian science if the leaders would combine to stop this framgentation, and encourage only the publication of serious critical papers where the work has been properly planned and the results fully considered. Good memoirs compel attention and gain recognition wherever and by whomsoever they are published.

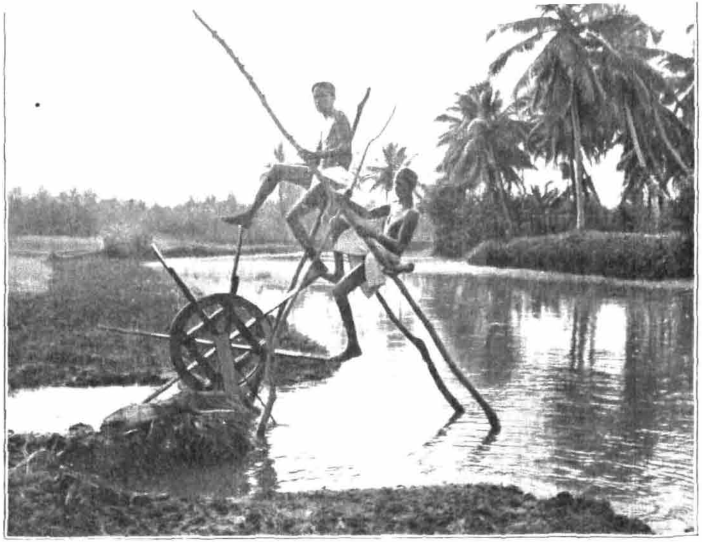
There is a considerable amount of good work in this vast mass of publications and it would be unfortunate if it all passed into oblivion. The best way of saving it would be the preparation of critical monographs, each by a specialist having thorough knowledge of his subject and able to assess the value of scientific evidence, summarising the results obtained, pointing out clearly where they differ from those recognised in the regular treatises and in what respects they represent advances in knowledge. These monographs would be of great value to teachers and to experimenters in India, and if well prepared they would be taken seriously by all agricultural research institutes ; they would not only show what has been achieved in India but would also cause other stations to examine any discrepancies between the Indian results and their own.

The third stage—extension of the results to the cultivator.

The great need at the present time, however, is the wider and fuller use of existing science rather than the development of new science. Repeatedly I was told at the Experiment Stations that their yields were approximately 50 or even 100 per cent. greater than those obtained by the surrounding cultivators. There remains a great gap to be bridged between what can on present knowledge be accomplished, and what is actually being done by the cultivators. An enquiry should be made into methods of propaganda and some of the more efficient of them should be more widely used.

The present method consists largely of arranging demonstrations on cultivators' plots. A new variety is sown alongside of the local variety so that the villagers may see how the new and the old compare ; or part of the land is cultivated with a new plough and part with old one. For an individual comparison a single plot suffices provided it is well enough chosen and no accidents happen. But for a group of improvements such as distinguish the experiment stations from the ryot's holding, the single plot is inadequate, and an entire small holding would be better.

The two methods should be regarded as mutually supplementary : the single plot has the merits that it is easy and inexpensive in operation, while the holding gives much fuller information but is of course more difficult and costly.



Water lift : human labour.
(Travancore.)

CHAPTER 2.

The crops--(a) The Cash Crops.

The common crops of India fall into two groups : those grown chiefly for sale, which we may call the cash crops, including cotton and other fibres, sugar cane, some of the wheat and oil seeds ; and crops grown for food, especially rice, juar, etc. The two groups need entirely distinct treatment. For the cash crops quality is an important factor, but it is impossible to define fully : the simplest and surest way is to obtain valuations and comments from expert buyers. For food crops, on the other hand, nutritive value is more important, and this should be assessed in association with medical experts.

The cash crops.

One of the most remarkable features in modern Indian agriculture is the increase in area under cash crops compared with that under food crops. The areas under cotton, sugar cane and wheat, have risen, corresponding with the increased area under irrigation, and the increase has kept pace with the increase in population. On the other hand the acreage under food crops show much less rise, and, if the figures can be accepted, the acreage per head of population has actually fallen. India possesses two good examples of research stations devoted to cash crops in each of which this important question of quality is in my opinion properly attacked : the tea research station of the Indian Tea Association at Tocklai, and the Cotton research station at Matunga, near Bombay. The Tocklai Station is the more complete in that it includes in the one organisation both producers and buyers, and it has devised special means of keeping close touch with both. The experimental samples of tea are submitted to expert buyers in Calcutta and in London for valuation and report : while at the other end of the chain considerable efforts are made to discover and to study the problems of the growers. Thus the staff have authoritative information as to the effect of the various practices on quality, and they can ensure that all of their results are known to, and can be used by, the whole body of the growers. The station is described on page 150.

The Cotton laboratory at Matunga works closely with the Bombay mill owners and experts, and is concerned chiefly with reducing the mill owner's rather undefined requirements to terms and quantities that can be handled by plant breeders. It is closely linked through the Indian Central Cotton Committee with all the Departmental Cotton breeding stations ; the Director has a voice in determining their programmes—in so far as they are financed by the Committee—and they have a voice in his. The cotton experimental field station at Indore is rather far away, a disadvantage, but one that is entirely unavoidable, because the conditions at Indore are suitable for field work while those at Matunga are not ; and on the other hand, Matunga is near to Bombay where the staff can

keep close touch with the mill owners. As cotton does not come within my purview I am not describing this Station, but its general organisation seemed to me to be very good.

The Council have endeavoured to make similar arrangements for sugar cane. The breeding is done at Coimbatore and the selections to suit the cultivator's requirements are made at various stations in the provinces : but a Sugar Technological Research Institute has been set up in the Harcourt-Butler Technological laboratories at Cawnpore (p. 108) where questions of quality, as the factory *understands the term*, can be studied. A Sugar Committee is to be set up, on somewhat similar lines to the Cotton Committee, which can take cognisance of all problems, economic, scientific and technical, associated with the growing of sugar cane and the production and marketing of the sugar. As soon as this arrangement has had time to settle down to good working order it should prove satisfactory.

The arrangements in regard to barley grown for export are also sound. The samples are produced at various stations in Northern India, and then submitted to the Institute of Brewing, London, where they are examined by experts having full knowledge of the requirements of the malting, brewing and distilling industries, and are reported upon in detail.

On the other hand, the arrangements for wheat and for rice do not appear to me to be so satisfactory. Investigations into quality of rice are being made at several centres, but there is no definition of what is meant by quality : there is no reference to expert buyers for market valuations or to medical authorities for grading according to nutritional standards. If a chemist is given a series of rices placed in a definite order based on some specific properties he may be able to find relations between composition and grading though it is always difficult to distinguish the true casual relations from merely fortuitous agreements. But if he has no guidance it is very difficult for him to get much out of his examinations. For a complex product like a seed the chemist can institute comparisons but he cannot so easily give absolute descriptions. For both these crops it is important to decide whether " quality " is to mean nutritive value or desirability in the market ; if the latter, in which market ; and to arrange the work accordingly. If market value is intended then some arrangements should be made with the buyers —an Indian group for the Indian market and a London group for the English market—to continue and extend the help already given on occasion to Sind and Punjab.

Sugar.

The Council can justly claim credit for great success in its activities in connection with the production and utilisation of the sugar cane crop. Since it began its work the area under cane has increased considerably and the old native canes have been largely supplanted by new varieties. The data are set out in Table 1.

TABLE 1.

Sugarcane Crop.

Acreage and production during 1935-36 (1).

Provinces and States.	Area (in acres).		Yield (in tons) of Raw sugar (Gur).	
	Current year. 1935-36.	Average of preceding five years.	Current year 1935-36.	Average of preceding five years.
United Provinces (*including Rampur* State).	2,249,000	1,597,000	3,336,000	2,063,000
Punjab	473,000	446,000	358,000	336,000
Bihar and Orissa	465,000	313,000	668,000	371,000
Bengal	325,000	224,000	560,000	330,000
Madras	131,000	114,000	360,000	322,000
Bombay (including Sind and Indian States).	121,000	99,000	313,000	256,000
North-West Frontier Province ..	58,000	49,000	63,000	55,000
Assam	35,000	32,000	35,000	33,000
Central Provinces and Berar ..	30,000	24,000	49,000	39,000
Delhi	3,000	4,000	3,000	2,000
Mysore	50,000	38,000	53,000	36,000
Hyderabad	59,000	38,000	99,000	60,000
Baroda	3,000	2,000	3,000	3,000
Bhopal (Central India)	5,000	(*a*)	5,000	(*a*)
	4,007,000 (*b*)	2,980,000	5,905,000	3,906,000 (*b*)

(*a*) Not available.

(*b*) Excluding Bhopal.

The increased acreage is mainly in the old sugar growing districts, there being but little opening up of new regions, and the total area still remains relatively small, only 4 million acres in British India out of 227 million acres cultivated—nevertheless its importance is out of all proportion to the area it occupies. So far as the cultivator is concerned sugar cane has a valuable educational

(1) From Department of Commercial Intelligence and Statistics in Indian Trade Journal Supplement, May 21st, 1936.

effect : he learns the advantages of modern varieties of crops, of fertilizers, of proper cultivation ; the need to watch for plant diseases and to seek advice when he is in difficulties. The Agricultural Officer has more chances of coming in touch with a sugar cane grower than with an ordinary small cultivator. From the national point of view India is a heavy consumer of sugar(1), standing second among the nations of the world, and being surpassed only by the United States (Table 2).

TABLE 2.

Consumption of sugar : in 1,000 metric tons : raw sugar value.

1934-35.

United States	5,870
British India	3,350
United Kingdom	2,283
Total—World ..	25,192

(Tables 1, 2 and3 are from Indian Trade Journal : Supplement, May 21st, 1936. Gur is converted into sugar according to the ratio 100:60. Where, however, the gur is eaten as such, which is the usual course in India, the conversion factor is more like 80 than 60 so that the Indian consumption given above is actually too low.)

An assumed and abundant supply of sugar is essential to India's happiness. Most of it—some 80 per cent.—is eaten as gur which is all produced in India. Much of the white sugar used to be imported : in 1929-30 the import was 939,600 tons ; but the Indian production has risen so high that imports have fallen to 23,000 tons only in 1936-37 (Table 3).

TABLE 3.

Production in tons.

Production in tons.	1934-35.	1935-36.	1936-37.
	Tons.	Tons.	Tons Estimated.
Sugar (from Cane)	578,115	912,100	1,031,100
Sugar (from Gur)	40,000	54,600	40,000
Khandsari sugar	150,000	125,000	125,000
Total sugar produced	768,115	1,091,700	1,196,100
Total sugar imported	222,900	201,200	23,000
Net production of Gur (estimated)	3,692,000	4,105,000	4,372,000

From its inception the Council gave a prominent place in its programme to sugar and it was thus able to provide the technical information necessary for implementing the Government's decision to foster the production of white sugar in India.

The programme was in three parts :

(1) The selection of canes better suited to the important sugar growing districts than the existing local varieties, and the improvement of their cultivation.

(2) The improvement of the local methods of making gur.

(3) The development of an advisory and research service for the sugar factories.

The selection and breeding work has been very successfully accomplished. The existing plant breeding station at Coimbatore was strengthened, and the investigations on the breeding of sugar cane so well started by Dr. Barber have been ably developed by Rao Bahadur Venkataraman, who has invented many devices for overcoming the numerous experimental difficulties. Provision was made for considerable experimental work to be done in all of the Provinces and several of the Indian States. Experimental farms were set up at Shahjahanpur by G. Clarke and at Muzaffarnagar to serve the United Provinces where about half the sugar cane of India is grown : the Station at Karnal is so near the borders as to serve a considerable area also ; while provision was made for experiments at Risalewalla, near Lyallpur and at Jullundur in the Punjab, which comes second in importance with 0.46 million acres ; at Musheri in North Bihar, Patna in South Bihar, which together have nearly as large an area (0.44 million acres) ; at Dacca in Bengal (0.28 million acres) and Gudiyattam in Madras. The experimental scheme, however, was not related to the area under crop in the province, for some of the most interesting work is done at Padegaon in Bombay Presidency, which has only a small area of sugar cane (79,000 acres) and at Hebbal Farm, Bangalore, Mysore State, where area of cane is very small.

Beside the plant breeding on the classical lines proceeding at Coimbatore, a special method involving mutilation or destruction of some of the chromosomes by X-rays is being tried by Dr. Badami at Bangalore, and whether this produces better sorts or not it promises to give new material of possible value for the breeder. His experiments should certainly be continued.

Although the breeding of cane is usually regarded as necessarily restricted to the South it could if necessary be done to some extent in parts of the North : viable seed has been produced at Musheri, near Pusa (Bihar).

This breeding and selection of cane is necessarily a slow business : 7 years elapse between the production of the new seed and the time when the new variety is fully tested and made available in sufficient quantity for distribution to the recognised farms from which it can be spread far and wide.

At present the selection is largely mechanical and it is possible that valuable new sorts may be overlooked and lost. The risk is minimised by making the test independently at a number of stations, but

it cannot be avoided till the Central Institute is able to find a really first class geneticist who could substitute proper scientific tests for the present mechanical ones. Meanwhile the work is being so well done that I have no suggestion to offer for its improvement. The new canes are so successful in practice that they are rapidly ousting the old ones(1). The improved varieties occupy a large proportion—no less than 74 per cent.—of the area under sugar cane : this being larger than for any other crop : out of the 4.14 million acres of sugar cane grown in British India in 1936-37, 3.07 million are stated to be under improved varieties.

The *experiments on cultivation, watering and manuring* are nearing the completion of the first series. At an early period the results should all be brought together, along with the analyses of the soils, and examined by a small group of experts, including a statistician, a soil specialist, a physiologist, and an agriculturist, to see what conclusions can legitimately be drawn and how far these agree with, or why they differ from, conclusions deducible from other good experiments made in the province. A new scheme of experiments should then be proposed for the second series. These should include practicable combinations of variety, irrigation, manurial and cultivation treatments, designed to give useful and trustworthy information without making the agricultural work and the recording too difficult. The statistician Mr. Vaidyanathan, is now at Rothamsted studying this type of design and full details will be discussed with him.

At an early stage a much simplified form of experiment should be tried on *cultivators' land*. Conclusions drawn from experiments at a research station are greatly strengthened if they are confirmed on other farms also ; and if they are not this shows the existence of some other factor playing an important part and needing investigation.

Considerable loss is caused by insect pests ; pyrilla and borers are mentioned specially in some of the recent reports. Investigations are proceeding but the field work needs further developing ; at each experimental centre close watch should be kept of the insects on the canes. This should not be confined to the bad attacks : it is at least as important to observe the early stages and to record the attacks *that began and then died down.* *Knowledge of the conditions under* which attacks became more intense and of those under which they died down, would form a solid foundation on which preventive or remedial measures could be devised. In view of the seriousness of the losses it is desirable to obtain the services of a visiting expert to discuss methods of control (page 219).

Utilisation of Molasses.

Closely associated with the sugar cane problems is the utilisation of molasses, the amount of which has increased greatly during recent years. The Director of the Imperial Institute of Sugar Technology, Cawnpore, has favoured me with figures showing the production and imports of molasses into India (Table 4).

(1) Indian Trade Journal Supplement May 21st 1936

--

TABLE 4.

Production and Imports of Molasses into India.

—	Production.			Available for Consumption.		
	Vacuum Pan Factories.	Khandsaris.	Total.	Imports.	Total.	Excluding Khandsaris.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
5 years preceding war.	30,000	50,000	80,000	93,354	173,354	123,354
1930–31 ..	68,645	200,000	268,645	102,024	370,669	170,669
1931–32 ..	115,808	250,000	365,808	40,191	405,999	155,999
1932–33 ..	186,658	275,000	461,658	31,991	493,649	218,649
1933–34 ..	230,154	200,000	430,154	2,401	432,555	232,555
1934–35 ..	255,817	150,000	405,817	415	406,232	256,232
1935–36 ..	369,028	125,000	494,028	..	494,028	369,028

A substantial part of the Khandsari molasses is converted into low grade gur by reboiling with sugar cane juice and something like 175,000 tons of the factory molasses is either converted into alcohol, used for tobacco curing, or directly consumed. But there remains the problem of finding some way of utilising the remaining 200,000 tons.

Various possibilities are discussed on page 109, they fall into three groups : conversion into food (including yeast) for human *beings or for animals ; the making of fermentation products such* as industrial alcohol(1), acetic acid ; and industrial utilisation as fuel, road surfacing material, fertilizer, etc. Of these I regard the first and second as the most important and the third as least important : it seems unfortunate to divert so much potential food to other purposes. The problems will become less urgent when the Indian sugar factories have attained the same high level of sugar recovery as the Java factories.

(1) The quantities of low proof alcohol produced in India during 1936-37 are estimated to be :—

	Million gallons.
Potable	6·8
Rectified	0·4
Denatured	2·3
Beer and stout	1·2
Total ..	10·7

For purposes of comparison it is interesting to note that the quantity of petrol produced in India and Burmah is 91 million gallons, most of which is consumed in India.

The Making of Gur.

Progress has also been made with the improvement of manufacture of gur in the villages though this task presents greater difficulties than the introduction of new varieties. The plant is usually hired out by the *banya* to the cultivators, or if the crop is new to the district the enterprising individual who introduced it may set up to make the gur. Many of the village mills are very inefficient, leaving behind in the bagasse a considerable amount of sugar—often as much as 20 per cent. of the total quantity (1). The evaporation of the juice in an open pan is inefficient, but as the trash and bagasse are both available as fuel the loss is not particularly important. The skimming of the concentrated juice varies greatly in effectiveness, resulting in a wide range of quality of the gur, and there is little attempt at clarification, except in a few regions where *hibiscus* is used for this purpose. Improvement in the mills would be perhaps the easiest to effect, and would result in considerable economy. Special attention is being given to this. Still greater improvement, if it could be brought about, would be to set up village factories with efficient mills for extracting the juice, vacuum pans for evaporation, and arrangements for clarification by filtering through charcoal : in this way higher yields and better qualities would be obtained. The *banyas* are usually good business men with some capital, and it is possible that, if suitable plants were available, they would purchase them. The problem appears to be one for a good firm of engineers. but in the meantime experiments aided by grants from the Council are being made at the Sugar Research Institute, in the Punjab. Bihar and Orissa, and in Bengal, with the purpose of trying to improve the making of gur.

The Sugar Factories.

The Council from the beginning recognised the necessity for a good research and advisory service to assist the factories in the production of white sugar and they set up an Imperial Sugar Research Institute at Cawnpore, housing it in the Harcourt Butler Technological Institute. Here a semi-commercial factory unit was established to furnish the staff with information and with opportunities to design or to test technical processes ; the expert in charge acts also as adviser to the factories. This section is evidently succeeding. The need for the work is shown by the wide variation in recovery of sugar at the different factories—from 4.4 to 11 per cent. of the cane, the general average being 9.5 per cent. (2).

The proposed Sugar Committee could appropriately take over the Sugar Research Institute.

---

(1) The difference in efficiency between the village process and a good factory is shown by the fact that from a given weight of cane the factory obtains as much sugar (99½ per cent. purity) as the villager obtains gur (80 per cent. purity). In both cases the amount of product obtained is about 10 per cent. the weight of the cane (page 102). The figures are :—

	Per cent.
Gur	10
Factory Sugar	9.5
Khandsari Sugar	5.5

(2) This compares with 5.5 per cent. recovery where Khandsari sugar is made.

TABLE 5.

Areas of land under different crops in British India.

Thousand acres—British India.

—	1915-16—1919-20.	1920-21—1924-25.	1925-26—1929-30.	1930-31—1934-35.
Net area sown	220,691	221,971	226,410	229,051
Irrigated area	47,391	46,969	47,889	49,870
Area under—				
Rice	79,331	78,981	79,167	80,367
Wheat	23,604	23,264	24,477	25,677
Jowar	21,817	22,669	21,352	21,826
Bajra	13,611	13,494	13,275	13,577
Gram	13,314	14,457	13,609	14,756
Sugar	2,797	2,757	2,830	3,233
All food crops including sugar (*b*) ..	210,614	209,494	208,658	214,746
Cotton	14,087	14,433	16,265	14,159
TOTAL—non-food crops ..	42,587	43,775	49,362	47,551

Summary.

	Thousand acres.
Increase in net area sown	8,360
Increase in food crops	4,132
Increase in non-food crops	4,960

TABLE 6.

Areas per head of population. British India.

—	1903-04—1907-08.	1908-09—912-13.	1913-14—1917-18.	1918-19—1922-23.	1923-24—1927-28.	1928-29—1932-33.
Net area sown, acres per head.	0·883	0·906	0·918	0·879	0·868	0·841
Acres under food crops per head.	0·829	0·862	0·873	0·833	0·803	0·786
Acres under food crops omitting sugar, per head.	0·818	0·852	0·862	0·822	0·792	0·774
Acres under non-food crops per head.	0·053	0·043	0·045	0·045	0·065	0·057
Population: *Millions* ..	237·6	243·8	245·3	246·9	259·2	271·5

(b) THE FOOD CROPS.

The quantity of food produced in India.

In no country is it easy to estimate the amount of food produced and in India the difficulties are particularly great. The areas under crops are fairly accurately known in most of the British Provinces but unfortunately considerable uncertainty exists as regards the Indian States and the permanently settled districts of the north east, Bengal, Bihar, Orissa and Assam which amount to about 20 per cent. of British India. There is now the possibility of an accurate survey of the areas under crop in Bengal.

The quantities of food produced, however, are not nearly so well known as the acreages. The published figures are obtained by the use of an old equation : Production area $\times$ standard outturn $\times$ seasonal condition factor. The standard outturn is not the average yield over a number of years, but the model value over a long period and so is unaffected by high or low yields of particular years. Unfortunately the standard outturn has not been redetermined for a long while, and it is very desirable that this should be done again : it involves a number of sample weighings. The seasonal condition factor can never be much more than a guess, though if it is unbiassed and done year after year by the same officer, and particularly if he has the opportunity of periodically checking his estimates, the results may not be unsatisfactory.

Professors Bowley and Robertson in their Report (page 39) point out that methods based on direct estimates would really be better.

It seems desirable to make a sample survey to test as far as possible the accuracy of the present methods and the possibility of improving them. Professor Mahalanobis has suggested a scheme for doing this which deserves serious attention.

The official figures as they stand show that the acreage under food crops, unlike that under cash crops, has not kept pace with the growth of population ; on the contrary there is an actual fall in the acreage per head. (Table 6). During the period 1908-09 to 1917-18 0.89 acres per head of population were devoted to food crops while during the period 1928-29 to 1932-33 the acreage had sunk to 0.79 per head. The population had increased by 28.7 millions but the area under food crops went up only by 2.6 millions acres, only 0.09 acres per head. The non-food crops, on the other hand, have kept pace with the population, the acreage per head being 0.044 in the earlier and 0.057 in the later of the two periods.

The statistics are not good enough to show how much the total production of food has varied and whether it has kept up with the population. Unless we assume (as some assert) that the villager has less food than formerly, we can only suppose that the yields have increased, and reports from the staffs of the Agricultural Departments confirm this view.

Almost the whole of the food crops are grain. They are consumed in the country and there is no important export so that " quality " in the sense in which it exists for the cash crops does not come into account here. But as they form the dietary of the people their nutritive value is of the greatest importance.

The recorded figures for production of all food grains are given in Table 7(1). These figures in so far as they are valid represent the amounts of all grains including oilseeds produced in the various provinces : they can be described as the amounts potentially available for consumption, and while not necessarily the same as the figures for actual human consumption, they may not in fact be far out. Some grain is exported from each province, and some is imported. If it is assumed that, on balance, the total may not be much affected ; and if, further, the figures accurately represented the actual production, they would need to be decreased by the amounts of husk (if any), the quantities lost on storage, and in transport and saved for next year's seed : no estimate of these can be made but the total is not likely to be less than 25—40 per cent. It is, however, safe to assume that the figures under-estimate the production. Cultivators all over the world under-estimate their crops in presence of an official, and the Indian ryot is not likely to be an exception. When a direct check was made on the production of cotton the estimates were found to have been 25 per cent. too low. For the food crops the difference may be of the same or even greater order (2). This under-estimate offsets the deduction necessary on account of seed and wastage, and if we assume they balance we obtain the average quantities of grain available per head per day set out in Table 7.

TABLE 7.

Production in oz. of all grains, including pulses and oil seeds per head per day. Cotton seed is not included.

Province.	Total grain million tons.	Population millions.	Total grain oz. per head per day.	Nitrogen grams per head per day.
Assam	1·6	8·6	18	7
Bengal	9·3	48·9	19	7
Bihar and Orissa ..	9·0	36·7	24	11
Bombay	6·1	20·6	29	16
Central Provinces ..	4·8	15·5	30	15
Madras*	10·4	46·7	22	11
Punjab	5·0	23·6	21	12
United Provinces ..	10·6	46·7	22	13

*Includes groundnuts which forms 20 per cent. of the whole.

(1) The quantities were supplied to me by the staff of the Imperial Council of Agricultural Research and by Sir Bryce Burt, and the data for composition are quoted from Dr. Aykroyd's publications.

(2) An interesting passage occurs in the Punjab Season and Crop Report of 1922-23 : "The principal exporting firms get fairly good results by assuming that the wheat outturn is 33 per cent. greater than the official estimate ". The Punjab Marketing Report, 1935-36, refers to this statement and sees no reason for supposing that conditions are different now. (Quoted from Report on the Marketing of Wheat in India, 1937.)

For what they are worth these figures suggest for most Provinces a production per head per day of about 20-22 oz. of all grains including pulses and oil seeds whether used for food or not : this would give a daily calorie value of about 2,000 or 2,500 according to the proportions of oil seeds taken ; and a nitrogen supply of about 12 grams daily. Bombay and the Central Provinces, however, come out higher, and Assam and Bengal lower, especially in nitrogen. The figures include no vegetables or milk products.

Unfortunately the figures are only very rough. In view of the supreme importance of this question of food production it is very desirable that better data should be available and I recommend that periodical estimates should be drawn up showing the amount of food produced.

Another means of approaching the subject is afforded by the numerous surveys of village dietaries that have been made.

The Punjab Board of Economic Enquiry in 1934 and 1935(1) made surveys of certain villages and the total quantity of grain eaten per head per day varies round about 15-20 oz., but for men only was 20 to 28 according to occupation. Lucas(2) put it 10.24 chhataks (about 20.5 ozs.) per head per day. Mrs. Wiser(3) found about 16 oz. per head was normally consumed in her village. In south-east Madras Dr. Aykroyd and his staff at Coonoor have made a survey in considerable physiological detail and calculated the results on the basis not of heads of population but of " consumption units ", *i.e.*, the equivalent number of adult men, using the scale adopted by the League of Nations Health Organisation in 1932, though Dr. Aykroyd points out that there is no evidence to show whether their scale is valid for India.*

Taking the " cross section " of a village in south-east Madras he arrived at the following dietary per " consumption unit " per day(4) :—

Protein.	Fat.	Carbohydrates.	Calories.	Percentage of total calories derived from cereals.	Calcium.	Phosphorus.	Iron.
g.	g.	g.			g.	g.	mgm.
62·7*	26·9	488·9	2,400	87	0·31	1·51	32·8

*Containing nitrogen 10 grams (conversion factor 6·25).

(1) Punjab Board of Economic Enquiry, Pub. 6 (C. B. Barry), Pub. 40, 1934 (S. K. Singh), Pub. 44, 1935.

(2) Economic life of the Punjab village. The figure of 15 ozs. quoted above is from C. B. Barry. Rates of Food Consumption by Non-Zemindars, Publication 6, Board of Economic Enquiry.

(3) The foods of a Hindu village of North India, Charlotte Viall Wiser, Bull. 2, Bureau Statistics and Economic Research, U. P., Allahabad, 1936.

(4) Diet surveys in South Indian villages, W. R. Aykroyd and B. G. Krishnan, Indian Jl. Medical Research, 1937, Vol. 24, pp. 667—688.

In order to compare these figures with those in Table 7, it is necessary to raise the latter by approximately one third : the figures are not good enough to justify a more elaborate coefficient.

It is highly important that these dietary surveys should be extended so that the actual facts may be known more definitely. The surveys should be really "sample surveys" and not "spot surveys", *i.e.*, there should be some definite method of selecting the villages *to be studied. Professor Mahalanobis is studying this problem.* Two independent sets of data can be collected :

(1) statements showing the actual dietaries, which can then be compared with the physiological requirements as set out by the medical authorities ;

(2) records of the prevalence of various diseases caused by deficiencies of essential nutrients.

It is unfortunate that the data for food production in India are somewhat uncertain, but in the meantime if we take the figures in Table 7 as a rough approximation of the average quantities available the question arises : are they sufficient ? Dr. Aykroyd is not yet prepared to lay down Indian standards but he inclines for the present to 2,600 calories as the average daily requirement of a man, a value which falls between the 2,200 suggested by Nicholls for an agricultural labourer belonging to the smaller races of the Tropics, and the 3,000 calories deemed necessary in Europe and America for the average man at average work. It seems a reasonable figure when allowance is made for differences in climate and in "average work". Whether it is really adequate is of course a question for the medical authorities to decide, but the agriculturist, at any rate, must accept it till they rule otherwise. Dr. Aykroyd(1) further suggests, as an average man's daily requirement in India, 65 grams of protein (*i.e.*, 10.4 grams nitrogen) probably 45—60 grams of fat, 20 mgms. iron, some 0.6 grams calcium and 1 gram of phosphorus ; but there are no Indian data as to these elements. He emphasises the importance of biological value of the proteins and points out that animal proteins are biologically more efficient than vegetable proteins ; he suggests that they should form at least one-fifth of the total protein. Milk, even skim milk, is the best for growing children, but eggs, fish, liver and meat are all good sources.

It is possible that the average supplies available approximately satisfy both the nitrogen and the calorie requirements when allowance is made for the fats and gur taken. A more serious defect is the lack of vitamins, especially of A and B and this is confirmed by the prevalence of the "deficiency diseases" associated therewith, *e.g.*, keratomalacia caused by deficiency of Vitamin A ; stomatitis due to vitamin B deficiency ; low hæmoglobin content due to iron deficiency. Calcium deficiency is also common. These missing elements can only be supplied by widening the diet and making it include more milk, vegetables, and fruit. Plantains are among the commonest fruits eaten, but they have low nutritive value. Tomatoes, oranges and other juicy fruits are much better. Oil obtained from the fruit of the Red palm (*Elaeis guineensis*), a West African tree.

(1) Health Bulletin No. 23, 1937.

that could apparently be grown in India, proved to be a valuable source of Vitamin A, and was therapeutically as effective as cod liver oil besides being much cheaper. It is clearly desirable to experiment with the growth of this tree in India so that the oil may be available in quantity. Dr. Aykroyd has drawn up an instructive table showing two dietaries : a common ill-balanced one, and a well-balanced diet which should be substituted for it(1). The data per consumption unit in ounces per day are :—

—	Ill-balanced diet.	Well-balanced diet.
Cereals	20	15
Pulse	1	3
Vegetables—		
Green-leafy	2	4
Non-leafy	2	6
Fats and oils	0·5	2
Fruits	..	2
Milk	2	8

The well-balanced diet does not require more but less cereals than at present, but it includes more of everything else, especially of vegetables fruit and milk, and one great need for the food supply is to increase the production of these three. It is essential, therefore, to increase the yield of the staple crops so as to liberate land for the cultivation of these supplementary foods. No improvement in ' quality " of the cereals or pulses will convert the ill-balanced into a well-balanced diet. I am strongly of opinion that in dealing with food crops intended for home consumption the agriculturist should *aim at securing the largest and healthiest crops possible*, but that he need not concern himself with trying to change their composition. The amount of alteration possible is too small to justify the expenditure of time and resources that can better be spent in other ways.

The first need in my view is to make a nutrition survey in each Province so as to discover what are the chief deficiencies in dietary : the medical authorities should then meet the agricultural experts to decide what crops, including fruits and vegetables, should be grown to supply the missing elements. The approximate quantities needed should be indicated, and the agricultural staffs acting along with the rural development authorities would then encourage by all means in their power the growth of these crops.

The nutritional survey should not in the first instance be over-elaborate : in most Provinces there is already a fair amount of material, probably sufficient as a first approximation, to allow the agricultural problems to be put in hand. More detailed studies could continue as part of the Public Health work of the Province in relation to nutrition of children, deficiency diseases, etc.

(1) W. R. Aykroyd and B. G. Krishnan, Indian Journ. Med. Res., 1936, Vol. 23, p. 731.

The " well-balanced diet " set out above costs about Rs. 5 per month for a growing adult and very little less for growing children : it is therefore out of the question in many households, but others, cheaper though not so good, have been suggested(1). The figures do not suggest marked protein deficiency but Dr. Aykroyd points out that it is greater than it appears because of the lower efficiency of the vegetable proteins as compared with those of animal origin. From time to time it is suggested that soya bean would be a valuable addition to the Indian dietary, but there is no evidence that it has any special value and until any is forthcoming there is no point in trying to develop its cultivation.

These nutritional deficiencies have been studied most fully in Madras but they probably hold also for most of India including the Bombay Presidency, Bengal, Bihar and Orissa. In the Punjab and the United Provinces, where more wheat and milk are consumed, the problems are probably different.

Dr. Aykroyd has pointed out that the deficiencies of the diet could most easily be remedied by the inclusion of animal products : milk, eggs, fish and meat. It is difficult to exaggerate the importance of increasing the milk supply : Dr. Wright is dealing with this. From the agricultural point of view the production of meat is the most costly of these foods, but supplies of fish could probably be increased. The Council already subsidises schemes of fish research at Calcutta and Madras and there is a strong case for further development.

Much more work should be done on the cultivation of the green leaf vegetables and demonstration fruit and vegetable gardens should be set up adjacent to the village where they can receive manure and water.

The new nutrition officer at Delhi.

Recently a nutrition officer has been appointed to act as liaison officer between the work of the nutrition laboratory at Coonoor and the Agricultural Research Stations at Delhi and in the provinces This is an admirable development which cannot be too heartily commended. Where there is so much to do it is important that he should begin straight away with the essential problems, leaving the minor ones to later occasions.

His first duty should be to collect the evidence obtained by the medical authorities and other public health workers as to the state of the nutrition of the villagers and townspeople, and discuss with the agricultural experts the best ways of remedying the observed defects.

It has been suggested that he should study the nutritive values of the new varieties of cereals and the relation of deficiencies to soil conditions. I do not agree with this view. There are of course differences in composition and in nutritive value of different varieties of cereals and of cereals grown under varying soil conditions. These may be of considerable importance in technical processes such as

(1) W. R. Aykroyd and B. G. Krishnan, Indian Journ. Med. Res., 1937, Vol. 24, p. 707.

brewing, baking, etc., but they are probably of far less importance in human nutrition. I am very strongly of opinion that the best varieties for home supply of food are those that give the largest *yields per acre.* The really vital matter is the food value per acre, not per ton, of produce.

It is particularly important that the work on human nutrition should not become diffuse : everything else should be subordinated to the two vital problems : what are the deficiencies in the village dietary and how best they can be overcome ?

With the greater part of the Report of the Nutritional Advisory Committee(1) I am in entire agreement.

Rice.

Rice is by far the most important crop in British India, occupying 67 million acres out of the 186 million devoted to food crops : it is the chief crop in Bengal, Bihar and Orissa, the Central Provinces and Madras, and it is surpassed only by wheat in the Punjab, the United Provinces and the North-West Frontier Province, and by jowar and to a less extent by bajra in Bombay. It is also one of the most interesting of Indian grain crops, for being indigenous to India it occurs in a large number of varieties which differ greatly among themselves. Among its most remarkable forms are the long stemmed paddies which grow in deep water so rapidly that they keep pace with the rising flood during the monsoon period.

Some very good work has been done in India on the classification and breeding of rice : the foundations were laid from 1913 onwards by G. P. Hector in Bengal and by F. R. Parnell in Madras, Hector showed that self-pollination was the rule but cross-pollination also occurred through the agency of the wind : he studied colour inheritance and worked out methods for artificially crossing rice. Parnell worked on somewhat similar lines, and incidentally studied the errors of experiment in field trials. These investigations have been developed, and the Council has organised a co-ordinated scheme of rice research in the Provinces, but especially at Coimbatore (Madras) under Mr. K. Ramiah ; at Nagina in the United Provinces ; Chinsura, Bankura and Dacca in Bengal ; Habiganj in Assam ; Sabour in Bihar ; Raipur in the Central Provinces ; Karnal in the Punjab, and on farms elsewhere.

At these stations new strains or varieties are selected to suit the widely varying conditions of the provinces. The labour involved is arduous and is perhaps the most disagreeable that falls to the lot of any agricultural experimenter ; it necessitates paddling about in gum boots in water or deep mud in the hottest part of the year with no shelter ; leeches and snakes are frequent pests while the stations are commonly in mosquito infested regions. But in spite of the difficulties the selection work is well done, large numbers of varieties and pure lines are examined, and vast masses of data are collected about their botanical and agricultural properties. The experiments on cultivation are also good and calculated to give the kind of information the cultivator needs.

(1) June 1936.

The work on manuring, however, is not always up to the same standard. At some centres it is satisfactory, and properly designed experiments show how different varieties react to differences in manuring. But at other centres the experiments are less well designed and the results are less definite. Few of the experiments give really useful information about the effect of fertilizers on the growth of rice. Yet there is great need for experiments, for by common consent an increase in yield is very desirable. The rice crop is peculiar among grain crops in its requirements and conditions of good growth. A uniform but simple scheme carried out at the various stations would give valuable information ; it should include nitrogenous and phosphatic fertilizers alone and in combination with and without green manure. I suggest that the statistician should collect the results of the first five-year period and set them out in a form in which they can be fully discussed by the proper sub-committee with a view to the adoption of a more definite scheme.

There is need also for more work on the water requirements of the different varieties of paddy in different environmental conditions. The possibility of making complex experiments including the effect of different watering and manuring on two or three varieties, similar in general type to that suggested for sugar, should be considered. The diseases problems are important, and I recommend that a critical summary of the position be prepared so as to guide the Council in the allocation of its funds between the various groups of rice problems.

In addition various problems connected with the physiology of the rice plant, and the sources from which it derives its nitrogen have been investigated. This work is described on page 178 ; while it may not lead to practical results it is a good subject for college investigation, and serves a useful purpose in the training of students. It should be kept to the University section of the Council's activities as suggested on page 5.

At several centres work has been undertaken on " quality " in rice. As already pointed out the term is ambiguous and has at least two meanings ; market quality, which is really commercial desirability ; and nutritive quality, which relates to value as a human food. The export of rice from India proper is so small that considerations of market quality hardly count so far as the export market is concerned, though there is an important home market for high quality table rice which the Marketing Branch is investigating : and if it succeeds in defining the grades by some system of marks the chemist may be able to discover some connection between composition and grading. By far the most important properties, however, are those associated with nutritive value.

I recommend, therefore, that the chemical investigations on " quality " of rice be examined by the nutrition experts, and either brought within their ambit or discontinued.

Some definite action seems desirable in relation to the use of milled and polished rice which is so strongly deprecated by the nutrition experts.

The rice crop is peculiar in that there are very few possible alternatives : on the lighter rice soils ground nut, sunn hemp, arhar,

juar, bajra and maize might to some extent be grown, but on the heavy soils there are usually no other possibilities but rice.

The acreage under rice is apparently declining. If this means that other grains are taking its place as food so that the dietary is becoming more varied, the change is probably to the good. I was on several occasions informed, however, that the yields are declining. No good figures seem to be available but if further enquiry indicated any basis for the belief it would be desirable for the Council to arrange for sample surveys to be taken in a region where the decline is said to be going on in order to obtain definite information on the matter(1).

Wheat.

The total area under wheat in India during the past five years averaged 32.1 million acres, of which 25.6 million acres are in British India. It is concentrated almost entirely in the North and towards the west. No fewer than 16.7 milion acres are in the Punjab and the United Provinces (9.0 millions in the former and 7.7 millions in the latter, about half in each case being irrigated, rather more in the Punjab and rather less in the United Provinces), the rest is in Central Provinces (3.6 million), Bombay and Sind (2.8 million) Bihar and Orissa (1.2 million) and the North West Frontier Province (nearly 1 million acres). Several of the Indian States, however, have important areas under wheat : the Central India States, Gwalior, Hyderabad and the Punjab Agency States, and Rajputana States have nearly 6 million acres between them, the first four groups each exceeding one million acres. The total area in British India has increased during the last 20 years from 23.6 million to 25.7 million, the increase being both on the irrigated and on the unirrigated land.

The average yields reported for the period 1925-26 to 1934-35 are given in Table 9.

Table 9.—Average yield of wheat and seed rate (2).

(1 lb. per acre).

——	Seed rate.	Yield.	——	Seed rate.	Yield.
Punjab	50	738	Sind	100	593
United Provinces	103*	786	Hyderabad	66	231
Central Provinces	86	444	Gwalior	85	458
Bihar and Orissa	100	882	Central India	85	382
Bombay	82	447			

*1¼ maunds per acre.

(1) *In the examination of the 38 years' records of a Bengal rice farm there was no evidence of deterioration of yield.*

(Haskim Amir Ali, Vishva Bharati Rural Studies, 1934, No. 1.)

(2) Quoted from Report on Marketing of Wheat in India, 1937, pp. 11, 320.

The great difference between the seed rates of the Punjab and the United Provinces requires investigation.

The return varies from less than 4-fold in Hyderabad to more than 14-fold in the Punjab : in the other regions it varies from 5 to 8-fold. The yields on irrigated land are naturally higher than on unirrigated ; thus in the Punjab, the only Province recording the yields separately, the figures are :—

Average yield on both types of land in the Punjab (1).

5 years 1927/28 to 1931/32.

——	Average.	Minimum District figures.	Maximum District Figures.
Irrigated	967	510	1,250
Unirrigated	572	400	720
Average for Province	791	..	..

The total production for British India is reported to be about 7.5 million tons and for the whole of India 9.3 tons.

TABLE 10.

Million tons : average for 1925-26 to 1934-35.

British India.		Indian States.(2)	
Punjab	2·9	Central India States ..	·3
United Provinces	2·6	Gwalior	·3
Central Provinces	·7	Hyderabad	·1
Bombay	·3	Punjab States	·4
Sind	·2	Others	·7
Others	·8		
Total British Provinces ..	7·5	Total Indian States ..	1·8

All India 9·3.

(From Report on the Marketing of Wheat in India, 1937, pp. 13 and 14.)

Of the total wheat area in British India nearly one half is irrigated (11.2 million acres) : the rice crop alone has a greater irrigated area (18.4 million acres). It is a rabi crop and from the irrigation point of view one of the best of all crops because it requires so little water : while rice may require 7 to 8 ft. (including rain) cotton may require only about 2½ ft. and wheat only about 1½ ft. (3).

(1) Published by the Director of Land Records.

(2) The figures for the Indian States are not complete and also they are far less accurate than those for British India. The total area of the Indian States is about 461 million acres, with a population according to the 1931 census of 81 million, but the Statistics for 1934-35, for example, relate only to 70 States with an area of 258.8 million acres and a population of 55 million, *i.e.*, 56 per cent. of the total area and 68 per cent. of the total population only. Even for purposes of comparison the statistics are incomplete, as the number of reporting States has increased from time to time.

(3) For examples of amounts of water supplied see "Statistics of Irrigation Water Distribution and Working of Distributaries of the Canals in the Punjab for the year 1932-33". (Government of the Punjab, Public Works Department, Irrigation Branch, Lahore, 1934.)

The possibility of combining wheat and cotton into one system is therefore very alluring : wheat being the rabi and cotton the kharif crop. Unfortunately the difficulties are very great and have not everywhere been overcome : they are more fully discussed on page 137.

Formerly there was a large export trade in wheat : for some years past it has been very small. The area of wheat grown, however, shows no corresponding diminution, suggesting that much more wheat is eaten in India than formerly :—

——	1910-11 1914-15.	1915-16 1919-20.	1920-21 1924-25.	1925-26 1929-30.	1930-31 1934-35.
Area under wheat thousand acres—					
British India ..	24,264	23,604	23,264	24,477	25,682
Indian States (1) ..	4,087	4,440	5,387	5,921	6,459
All India	28,371	28,044	28,651	30,398	32,141
Exports, thousand tons ..	1,239	668	453	163	46

The latest figure available for area is 33.6 million acres. Further increases in wheat area seem probable as the irrigated areas increase.

When the Lloyd Barrage scheme was set up in Sind it was intended that the area under wheat should finally attain 2 million acres. The present acreage is about 1 million : it remains to be seen how far the initial plan can be realised, but further expansion is almost certain to come in one or other of the Provinces especially in the Punjab now that the Sutlej valley scheme is sanctioned. The possibility of over-production was discussed by the Crop Planning Sub-Committee of the Advisory Board of the Imperial Council of Agricultural Research in June 1934 but no clear evidence was forthcoming. *It was decided not to stimulate further production,* but also not to discourage it. A steady demand for wheat will inevitably call forth the supply.

Experimental work on wheat in India.

The foundation for the experimental work on wheat was laid by Mr. W. H. Moreland, for many years Director of Land Records and Agriculture in the United Provinces who collected various wheats and sowed them so that they might be studied. J. Hayman, the first Deputy Director of Agriculture, carried out the work, and Mr. B. C. Burt (now Sir Bryce Burt) grew the collection on the Cawnpore experimental farm—the first experimental farm to be set up in India(2) and showed them to Mr. Howard (now Sir Albert Howard) and Dr. Martin Leake who at once recognised

(1) See Note 2 on page 25.
(2) It was started by Mr. (later Sir) Edward Buck about 1880.

the importance and value of some of the varieties and used them in their later work. The actual founders of the modern Indian wheats are unquestionably the Howards, who had the artist's eye for picking out the varieties likely to do well and those that would not ; in consequence the selections and crosses finally made have proved remarkably successful. Their work began in 1905 and Pusa 4 and Pusa 12 soon proved valuable in the United Provinces and the North West Frontier Province.

Mr. David Milne carried out systematic selection of the Punjab wheats at Lyallpur from 1907 onwards, and multiplied the best strains for distribution. In consequence of all this work a considerable area is now sown with the improved Pusa and Punjab wheats ; over all India an area of about 7 million acres, or 20 per cent. of the total was in 1934-35 sown with improved wheats(1). Of these Punjab 8-A, bred at Lyallpur, is said to be one of the most popular, accounting for about 2½ million acres—nearly one half of all the area under improved wheats. The Central Provinces and Central India, however, have not benefited so greatly from the improvements as they grow a good deal of durum wheat, which have not yet been so fully studied as the others.

From the papers and the close touch with the English millers, it seems clear that the Howards had always in view the requirement of the English market and they enlisted the assistance of Mr. (later Sir) Albert Humphries, a well-known miller, in assessing the quality of the wheats they bred. The English value for "strength" was adopted. This purpose was justified by the considerable export of wheat to England in those days. Several factors contributed to the ready saleability of Indian wheat on the English market. It was certainly dirty, but it was cheap and it contained less moisture than some of its competitors so that its real price was even lower than its market price. In pre-war days it made a useful combination with the Russian wheat, because while Russian wheats yielded rather soft and runny doughs, Indian wheats gave "short" and clay-like doughs, and the two together gave satisfactory results. Modern Russian wheats no longer show this defect. English millers still, however, find use for Indian wheats when the price is sufficiently low, and in point of fact they are now using the not dissimilar Persian and Iraq wheats.

The modern improved Indian wheat is very different from the ordinary Karachi wheat and compares favourably with good Australian, Canadian and South American samples ; if ever it became the predominant wheat exported from India it would readily compete with them in England provided it were clean and properly graded. This would mean the setting up of proper cleaning machinery and elevators at the Indian ports as well as adequate arrangments for grading and control of shipments—altogether a big business.

The important question of policy arises : should the Agricultural Departments in India aim at securing a place in the English market or should they develop the home demand ? If the aim is the English market then vigorous steps should be taken to export

(1) 34.5 million acres of wheat were sown in that year.

only graded improved wheats, which should therefore be produced on such a scale that they can displace the old varieties on the English market. If, on the other hand, it is proposed to develop the home market then English standards of "strength" should no longer dominate the investigations but close study should be made of Indian requirements, which are almost certainly different. By far the greatest part of the wheat used in India is ground in hand mills or small power mills and made into chapatis : there is not much demand for the white flour produced by roller mills which is the most popular kind of flour in England(1). Instead of studying the milling and baking qualities of Indian wheats only from the standpoint of the roller mill it would be far better to study their behaviour in the *chakki* and for making chapatis.

On the question of policy I express no opinion. Two important factors must be taken into account. In favour of the export market is the consideration that a large export trade in normal years affords the best guarantee against famine in years of low yield. In favour of developing the home consumption is the fact that Western nations having a choice of cereals always choose wheat, maintaining that it is the most suitable to the normal man's life. Physiologists may point out that other grains are richer in various constituents : that bajra contains more fat and has a higher calorie value : that ragi contains more calcium : nevertheless people who have the choice take wheat. Against this it has been argued that wheat being a rabi crop is less suitable as a food than the kharif crops, bajra, cholam, ragi, maize, etc., because it takes water that might be given to more lucrative cash crops ; further, that these kharif crops give higher yields than wheat ; in the Punjab, for instance, 20 to 25 maunds per acre against only about 12 of wheat. In spite of all this, however, if one may judge from what is happening elsewhere it seems probable that the consumption of wheat in India will still further increase and investigations as to quality should therefore be directed mainly to Indian requirements.

The Council should form some estimate as to the extent to which an export trade is desirable so as to guide the Departments in regard to the sowings. The export trade and the Indian roller mills will require improved strong wheats and enough should at least be sown to provide these: the home trade may prefer some other variety in which case the necessary multiplication of seed would need to be done.

Meanwhile a new factor has come into prominence : the necessity in resistance to rust, which by common consent is the most serious disease of wheat in India. One of the Pusa wheats—No. 114—is fairly rust resistant and so is spreading in Sind : a watch for other varieties is being kept by all wheat breeders. Professor K. C. Mehta, of Agra, is studying this question of rust resistance and in conjunction with Dr. Pal of the Imperial Research Institute,

(1) In 1936-37 about half a million tons of wheat were taken by the roller mills, leaving about 9 million tons for the hand or small power mills.

Delhi, is breeding rust resistant varieties from which it is hoped to select some possessing high yield and vigour.

The work is described on pages 98 and 148, where also *Professor Mehta's recommendations are given. These should be* seriously considered with a view to giving practical effect to the underlying relationships which he has worked out.

Barley.

Barley occupies only about 6½ million acres in British India, two-thirds of the acreage (4.17 million) being grown in the United Provinces, and the rest in Bihar and Orissa (1.2 million acres) and the Punjab (0.61 million acres). But since good malting samples command a price far above that ruling for ordinary cereals it may have special value as a potential cash crop.

For many years now Indian barleys have been exported to England and some have been taken by maltsters, though never at a high price. Numerous attempts have been made to produce improved varieties that would obtain a better price and a more secure position in the market.

Two types of barley are used by English brewers : two-rowed and six-rowed : they serve somewhat different purposes in the brewing processes and they are not altogether interchangeable. There is no evidence that India could produce the two-rowed barleys, *but some of the recent six-rowed varieties* compare favourably with the Californian barleys at present used.

If Californian barley were indefinitely obtainable in its present quantity the Indian barleys would have difficulty in supplanting them. Two new factors have, however, recently come into the situation. It seems probable that the supplies from California will fall off. The United States are no longer " dry " : the manufacture of beer has recommenced, and necessitates the use of much of the Californian barley that used to be exported. Further, the preference given at the Ottawa Conference confers a price advantage on Indian barley as against Californian. For these two reasons, therefore, the improved varieties may be expected to sell *in England as soon as they are obtainable in commercial quantities,* provided always, and this is extremely important, that they can be shipped clean and free from the Khapra beetles that have in recent years so much damaged the reputation of Indian barley abroad. This would probably mean the setting up of some large scale cleaning plant at the port, and shipment under the Certificate of a Government inspector.

The millets : Juar, Bajra and Ragi.

These three crops occupy nearly 40 million acres in British India and about 63 million acres in the whole of India : Juar

(*Andropogon sorghum*) is the most important, Bajra (*Pennisetum typhoideum*) comes next, and Ragi (*Eleusine corana*) third :—

Million acres 1934-35.

——	British India.	Indian States.	All India.
Juar	21·8	14·5	36·3
Bajra	13·1	7·1	20·2
Ragi	3·7	2·8	6·5
Total ..	38·6	24·4	63·0

The acreages are far below those for rice but they exceed those for wheat or any other crop. The special feature of the millets is that they are kharif crops sown just about the time when the monsoon breaks : and they may receive little or no water beyond what the rain brings, though if water is available it is of course given when necessary. They are, however, associated with dry rather than with wet conditions : they are the chief crops in the non-irrigated and dry farmed areas ; usually they are more or less complementary to rice, *i.e.*, in districts where there is a large area of rice the area under the millets is small and *vice versa*. Hyderabad State has the largest juar area (8.8 million acres) ; Bombay has a little less (8.4 million acres) but it has the largest acreage of bajra (4.8 million acres). Madras and the Central Provinces have respectively 5.1 and 4.3 million acres of juar : the Punjab, Madras, Hyderabad State and the United Provinces have also considerable areas of bajra, while Mysore has the largest area under ragi (2.3 million acres) followed by Madras (2.15 million acres).

The millets serve a dual purpose : the grain is used for human food though there is a certain social distinction involved ; the millets being associated with the lower rather than with the upper grades of society(1). The stalks form, in many districts, the chief food of the cattle for some six months in the year.

A certain amount of work has been done on these crops in several of the Provinces but none of the selected varieties have spread far, and there are no successes comparable with those obtained with sugar cane, wheat, or rice, to which the older plant breeders had confined their attention. There has, however, hardly been time to find improved sorts, and certainly no time for them to spread. Moreover these crops are indigenous : they have been grown for hundreds, if not thousands, of years, and considerable selection has already gone on in the villages. There is no indication of any possibility of drastic change comparable with that made by Dr. Barber

(1) "Many of the hostel superintendents told us that they had the greatest difficulty in persuading the children to eat ragi and other kinds of millet, even when millet is the staple food of the district from which they come. Adolescent country boys and girls, who are hoping to raise themselves above the status of their parents, feel entitled to consume the cereal of the townsman and the educated classes—milled rice." W. R. Aykroyd and B. G. Krishnan, Indian Jl. Med. Res., 1937, Vol. 24, p. 723.

in sugar cane when he succeeded in crossing it with the wild *Saccharum*. Finally, these crops have definite taste, and the peasant accustomed to one variety is not likely to change if the taste is different.

With the establishment of a millet section at Coimbatore and at Indore, and experimental schemes in Nagpur, Lyallpur, and in Bombay in connection with the dry farming scheme in the Punjab and the Central Provinces, one may hope for improved strains, giving higher yields or being more resistant to drought, pests and diseases, and to the troublesome parasitic plant Striga (page 179).

More work is, however, needed, in view of the importance which the nutrition experts attach to the millets. In particular some of the humbler varieties such as Kodon, the poor man's crop, should be more studied and either improved or replaced by something better.

The Pulses.

The Council has no schemes for studying the pulses but in view of their importance as sources of protein I suggest that a conference should be held with the nutrition experts to discover whether more work could usefully be done, and, if so, on what lines.

Vegetables.

A considerable amount of good work is being done on potatoes, one of the most useful vegetable crops ; it is described on page 147. In view of their importance more attention should be paid to other vegetables, particularly the cheaper and more easily cultivated of those commended by the medical authorities as supplying vitamins or mineral constituents deficient in the ordinary diet. The peasants in Northern India can grow very good vegetables, and at some of the shows I have seen specimens that could have been exhibited with satisfaction anywhere. A marked extension of vegetable growing, as of fruit, is very desirable.

Fruit.

Although fruits of various kinds have been grown all over India from time immemorial it is only in recent years that efforts have have been made to put fruit production on an organised basis. The natural inclinations of the people to eat more fruit have been stimulated by the medical advice that fruit and vegetables are among the best sources of the vitamins and other substances missing from the ordinary Indian dietaries. Consumption appears to be greater than production, for there is a considerable import of apples from the United States and Japan, and of grapes and oranges from the United States. In consequence every Department has taken up the question of fruit growing within its province and some very useful work has been begun at Ganeshkhind and elsewhere which deserves every encouragement.

The range of fruits that can be grown in India is unusually wide. All the ordinary European varieties can be grown in the high country in the North of India ; while the tropical fruits can be grown in the plains and in Southern India(1).

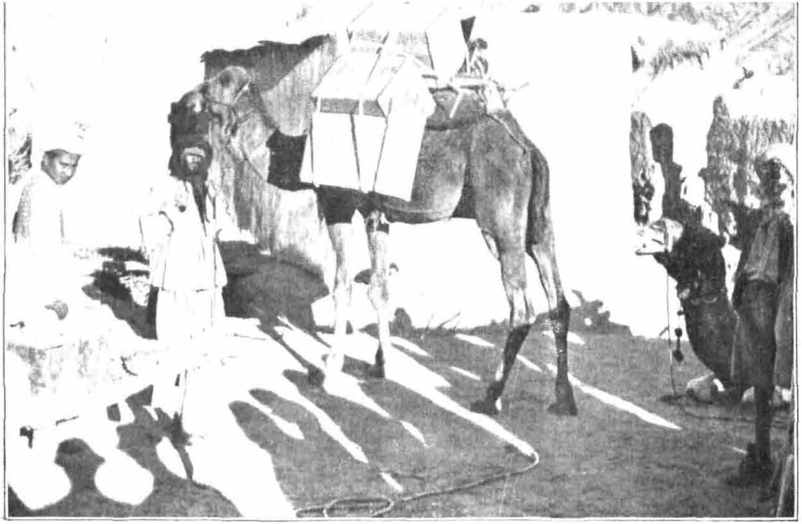
The North West Frontier Province, Baluchistan and Kashmir all produce fruits familiar in Europe : apples, plums, apricots, peaches, grapes, etc. Other hill districts in the Punjab, the United Provinces and the Nilgiris produce strawberries and apples. The possibilities of development in the hills seem considerable. The plains produce mangoes, leitchis, papayas and oranges, while Bengal and the Peninsula produce bananas and in the wetter regions, pineapples. Mysore is remarkable in being able to produce two crops of apples in 12—15 months, which is I believe a unique achievement, in addition to the grapes, mangoes and bananas which do very well there.

There are two aspects to the problems of fruit and vegetable production : supplies to the towns and supplies to the villages.

The town supply involves difficult questions of quality, transport, storage and marketing ; they can be solved but usually require some special machinery. Transport is so important and liable to be so difficult that no area should be put into fruit unless it seems clear that adequate transport arrangements can be made. The production problems are fairly straightforward and a good start has

(1) Mr. H. C. Javaraya has furnished me with the following list of common fruits in the various provinces :—

Baluchistan	grape, peach, apricot, plum, melon.
N.-W. Frontier	the above and also quince, apricot, pear, orange, sweet lime.
Kashmir	apple, pear, cherry, plum, apricot.
Punjab	orange.
Kulu Valley ..	apple.
United Provinces : Nainital	apple, strawberry.
elsewhere and on plains	mango, loquat, leitchis, melon, pineapple.
Assam	pineapple, orange.
Bengal	pineapple, banana, mango, orange, melon.
Bihar and Orissa ..	mango, leitchis.
Central Provinces ..	orange, banana.
Hyderabad-Deccan ..	grape, orange.
Bombay	mango, orange, banana, strawberry, fig, grape.
Madras	mango, orange, banana, grape, pear, pineapple.
Nilgiris	strawberry.
Mysore	apple, grape, mango, banana.
Travancore	banana, pineapple.



Fruit transport from Quetta.

been made with them. The first essential is to clear up the rather considerable confusion in regard to the varieties : the indigenous fruits—mangoes, bananas, etc.—occur in large numbers of varieties, some of which, however, have different names in different places.

Good stocks must be selected and produced in quantity for budding or grafting and having done this perhaps the most difficult task is to arrange for distribution of stocks and trees true to type : this must be done either from Government farms or from commercial nurseries which are rigidly inspected and certified.

The extension of fruit culture will almost certainly be accompanied by an extension of fruit pests. The San Jose scale has already appeared in Northern India and may do much damage unless it can be checked. The Imperial Research Institute should be empowered to keep a close watch on all potentially harmful pests and advise as to the proper precautions and remedies.

A special feature of large scale fruit growing, and one which makes it very attractive to men who like the organisation of an estate and the possibility of doing well, is that it requires for full success and development in each important fruit growing centre of certain subsidiary industries. The most important of these is the preserving of fruit and vegetables by various means and the making of fruit products, so that unmarketed fruit can be converted into some marketable form and potential waste material can be used to good purpose. Investigations on these lines are being made at Lyallpur. Other industries, smaller but also important, are the keeping of bees, which beside giving honey play an important part in the fertilizing of the blossom and the setting of the fruit ; and the making of baskets or boxes as containers : this in turn necessitates the collection or cultivation of suitable shrubs or trees to furnish the necessary material.

Thus the cultivation of fruit leads to the employment of far more labour than the cultivation of other crops, and it is admirably suited for graduates of agricultural colleges who may wish to become something better than ordinary farmers.

The problem of fruit and vegetable supplies for the villages is, however, on a different footing. Here the need is for cheap hardy fruits and vegetables, which can be grown around the village and which require nothing in the way of costly management. The problems are those of action rather than of research. Finality in fruit and vegetable culture can never be attained, and there will always be need for more experiments on selection, propagation, cultivation and general management. But in the meantime a great deal more is known at the Experiment Stations than is practised in the villages, and the chief need at the present is to spread the cultivation of fruit and vegetables as widely and as speedily as possible. Adequate place should be given at the experiment stations to easily cultivated and inexpensive fruits and vegetables so as to keep them prominently before all interested in the development of the countryside. But the work must be carried into the

villages. The planting of mango trees along the roadway leading to the village ; of vegetables on any available site near the village, *e.g.*, the slopes of the nullahs where these are cultivable, and where possible the planting of orchards, are really urgent matters. At most of the experiment stations where fruit is grown I found men sufficiently skilled in the art of fruit and vegetable production to be able to render great help to the villages. Still more important, *the help of the village teacher, where there is one, should be enlisted.* This extension of fruit and vegetable growing is so important that it should be pushed forward as rapidly as possible.

Reference has been made to the increased interest in fruit growing but the statistics reveal a rather remarkable trend. The fruit areas are not shown separately but are included with vegetables and root crops ; the total areas have declined since 1914-15 (Table 11) in spite of the increase in population, particularly on the eastern side : Madras, Bihar and Orissa, Bengal and also Bombay : the decline is less marked in the United Provinces and the Punjab and there has been an actual increase in the Central Provinces and the North West Frontier Province. From the reports of the Marketing Officers, it appears, however, that the areas under fruit have increased [1].

TABLE 11.

Area of Fruit and Vegetables (including root crops), growing in India since 1914-15 : average 5 year periods.

Five year period.	Million acres Average.
1914-15—1918-19	5·70
1919-20—1923-24	5·42
1924-25—1928-29	5·06
1929-30—1933-34	5·00
1934-35	4·82

Oilseeds.

Oilseeds occupy about 5 per cent. of the total sown area in British India (14½ million out of 259 million acres) : but the precise acreage is difficult to ascertain because they are often sown in rows among other crops. They are concentrated chiefly in Madras (28 per cent. of the total area grown), the Central Provinces (13 per cent.), Bihar and Orissa (12 per cent.) and Bombay (11 per cent.). Cottonseed is not included in these acreages : practically all that is not wanted for sowing is fed direct to cattle, a rather wasteful process.

(1) I am indebted to Mr. H. C. Javaraya for a summary of all the available data on this point.

The estimated areas and yields for all India are given in Table 12.

Table 12.

Acreage and production of Oil Seeds.

—	Estimated Area (1). Thousands Acres.						Estimated Production. Thousand Tons.					
	Average 3 years. 1927-28—1929-30.			Average 3 years. 1933-34—1935-36.			Average 3 years. 1927-28—1929-30.			Average 3 years. 1933-34—1935-36.		
	British India.	Indian States.	All India.	British India.	Indian States.	All India.	British India.	Indian States.	All India.	British India.	Indian States.	All India.
Ground Nut ..	4,914	927	5,842	4,675	1,917	5,592	2,291	230	2,521	1,954	526	2,481
Castor	507	885	1,392	421	1,055	1,476	61	61	122	47	75	122
Linseed	2,622 (561)	452	3,074	2,700 (622)	658	3,358	326 (86)	24	350	340 (99)	54	393
Sesamun	4,373 (830)	1,098	5,471	4,561 (876)	1,129	5,723	392 (73)	106	498	383 (79)	87	469
Cotton	15,816	10,095	25,912	14,954	9,747	24,701	653(2)	358 (2)	1,011 (2)	620(2)	328(2)	948 (2)

(1) The note on page 25 in regard to Indian States holds here also. Two other qualifications are necessary:

(a) *Castor seed.* —The figures do not include any estimate for the mixed crop, *i.e.*, seeds sown in the same fields with other crops, in the United Provinces for which there are no reliable data at present.

(b) *Linseed, Rape, Mustard and Sesame.*—The figures include the highly conjectural estimates for the mixed crop in the United Provinces shown in brackets alongside them.

(2) Baled. These are figures of raw cotton. Figures of cottonseed are not available.

There has been a marked change in the fate of the oil seed crop in recent years. Prior to the war there was a large export, but this has fallen considerably and except in the case of linseed, still seems to be falling. Much of the ground nuts, and most of the rape, mustard, sesamum, safflower and niger are now used in India as food : about a quarter of the ground nuts are exported, and a large proportion of the castor and linseed (Table 13). These are sent out mostly as seed, but there is a substantial export of ground nut and linseed cake and some rape cake and castor oil—used as lubricant. The export of cake finds some explanation in the fact that in absence of a cattle fattening industry linseed cake is not much in demand in India, while some of the ground nut cake goes to Ceylon as manure. Of the cakes that remain in India, castor and neem cakes are used as manure, and the others as foods for live-stock.

TABLE 13.

Oil Seeds : Total exports from ports in British India (1) *and values in £ sterling.*

—	Seeds.				Oil.				Cake.			
	Average 3 years 1927-28—1929-30.		Average 3 years. 1933-34—1935-36.		Average 3 years. 1927-28—1929-30.		Average 3 years. 1933-34—1935-36.		Average 3 years. 1927-28—1929-30.		Average 3 years. 1933-34—1935-36.	
	Thousand tons.	£ thousands.	Thousand tons.	£ thousands.	Thousand gallons.	£ thousands.	Thousand gallons.	£ thousands.	Thousand tons.	£ thousands.	Thousand tons.	£ thousands.
Grounds nuts	705	12,848	490	4,803	237	39	427	40	161	1,378	215	920
Castor	116	1,797	70	659	507	82	1,319	143	..	..	..	..
Linseed	209	3,388	261	2,445	97	18	71	9	69	636	55	265
Rape	62	1,015	43	374	246	54	265	25	47	392	29	120 (2)
Sesamum	17	353	7	81	146	32	127	15	..	..	..	..
Cotton seed	114	830	3	10	..	..	..	..	..	..	..	..
								All cakes	292	2,526	312	1,359

(1) These are from British India ports only : the exports from other ports are not known but must be considerable. The States of Kathiawar and Travancore have recently published statistics and the exports of groundnuts, etc., from Kathiawar for the last three financial years were as follows :—

	1934-35.	1935-36.	1936-37.
Groundnuts (Tons)	36,639	61,279	51,888
Groundnut Oil (Gallons)	17,170	620,291	802,779
Groundnut cake (Tons)	42,863	26,733	31,369

(2) Chiefly to Ceylon.

Oilseeds are of great importance in human nutrition and as crops they have many agricultural advantages : they fit well with irrigation schemes ; and the chief of them, the ground nut, has the further advantage that it is a leguminous crop and so improves the productiveness of the soil : indeed advantage is taken of this property in parts of Bombay and the Central Provinces and Berar, where groundnut precedes cotton in the rotation to an increasing extent.

It is therefore very desirable to encourage their cultivation, and a co-ordinated scheme of research has been set up with the view of improving both yield and quality of the crop. The necessary selection and breeding work has been put in hand on a properly organised plan at Delhi, Coimbatore, Lyallpur, and other centres. The brassica oilseeds are likely to give some trouble but the work is proceeding satisfactorily : it would be improved if a first class geneticist could supervise the procedure and the classification.

Search for rust resistant varieties of linseed is made and at the Harcourt Bulter Technological Institute the various oils are studied chemically and physically.

The programme of work is good and it is being satisfactorily carried out.

Mixed Cropping.

The agricultural economic aspects of mixed cropping should be studied in view of the widespread use of this practice and the probability that some crops mix better than others.

Fodder crops and grazing for livestock.

Under present conditions the amount of food produced is insufficient for the large number of animals in India and in consequence many of them are inadequately fed. So long as this continues the efforts now being made to improve the quality of the livestock by distributing better bulls cannot attain wide success. The bullock, as the source of power, usually comes off best, but the cow is not so well fed and in consequence of a low diet gives only poor yields of milk. If it were feasible the best course would be a large reduction in numbers of animals so as to bring the livestock population more into line with the supplies of food, but this cannot be done rapidly. Some gradual reduction will no doubt come about by economic pressure as the grazing grounds become more closely settled for cultivation, and as the castration of scrub bulls becomes more commonly practised. Improvements in the farm implements, and particularly in the bullock cart, would reduce the need for so many bullocks in the village. It is commonly stated that the cultivator must have large numbers of animals in order to obtain sufficient farmyard manure : this is only partially true. The quantity of manure produced depends on the amount of food eaten, and a given quantity of food produces more manure if fed to one animal than if fed to two. For the present, however, the only practicable solution is to increase the production of animal food.

Forest grazing.

Over a large part of India the only food for the animals consists of the stalks or straw of the grain crops : rice, wheat, juar or millets and such grazing as is obtainable. A few Provinces, however, grow definite fodder crops, especially the Punjab, Bombay and the United Provinces :—

——	Million acres. Total area sown.	Fodder crops.	Fodder crop as per cent. of total.
Punjab	29·8	4·8	16·1
Bombay	34·1	2·6	7·6
United Provinces	43·4	1·4	3·2
Central Provinces	27·5	0·46	1·7

The others have a smaller proportion of fodder crops.

Grazing.

*The grazing areas fall roughly into two groups associated res-*pectively with forest and with cultivable wastes : the latter are much more important. Only about 10 per cent. of the cattle of the five Provinces possessing much forest have access to forest grazing : the figures are given in Table 14 (p. 40). The acreage of forest grazing available per head is only an average figure and it includes considerable areas that are almost inaccessible : the density of livestock is much greater on the areas actually used.

Where the grazing is under the control of the Forest Department, or where, as in part of Madras, it is leased in blocks for sub-letting subject to certain conditions, the pasturage remains good and there are possibilities of improvement. But where the Forest Department has no control the losses have been greater. Considerable areas of wooded pasture—marginal land between grass and forest—in the regions of low rainfall have been taken out of the Forest department control and handed over to a non-technical department or to the panchayats : here grazing has been more or less unrestricted and losses have resulted. In the Punjab foothills where unrestricted grazing has been given as a right, the vegetation is denuded and soil erosion has set in : some really appalling losses have already occurred and more can be expected.

The improvement necessitates two regulations :

(1) restriction of the period during which grazing is permitted : all animals being excluded during the first 3 or 4 months of the monsoon so as to give the herbage a chance of developing ;

(2) rigid restriction of the numbers of animals finally admitted ; the restriction being either by regulation or by increasing the grazing fees. There are no set rules about acreage but 2 acres per head is recognised as a suitable standard for cattle, subject of course to variation according to conditions.

Table 14.

Number of animals using grazing land and of those unable to do so. (1)

Province.	Forest Grazing Lands.		Nos. of Livestock in millions utilizing forest gazing.			Non-Forest Grazing.		Total Nos. of animals. Millions.	
	Total area of forest lands in square miles.	Area open to grazing in square miles.	Cows and Bullocks.	All Live-stock.	Acres available per head.	Livestock in millions.	Area available square miles.	Cows and Bullocks.	All Live-stock.
United Provinces ..	6,000	4,000	0·88	1·3	2	42	31,000	23·2	43·3
Madras	16,000	14,000	1·4	2·2	4	41·3	51,000	17·8	43·5
Punjab	5,200	4,700	0·87	2·7	1·1	23	42,000	9·8	25·8
Central Provinces ..	19,400	17,000	2·5	3·1	3·5	13·1	30,000	11·6	16·2
Bombay	14,000	12,400	1·5	2·4	3·25	11·5 (3)	40,000	7·4	13·9
Total ..	60,600	52,100	7·1	11·8 (2)	2·8	130·9	194,000	69·8	142·8

(1) Taken from a Report on the better utilization of forest areas for grazing 1937 (Sir C. G. Trevor, Chairman).

(2) Incluing 1,166 buffaloes and 3,381 sheep and goats.

(3) Including Sind.

Instances could be multiplied of successful results obtained in this way.

The great majority of the livestocks—90 per cent. according to the above figures—have access only to non-forest grazing and this includes a considerable amount of very variable land much in need of fuller classification and study : it mostly falls within the category of " cultivable waste land not available for cultivation " of which there are large areas in all provinces. Much of it could be utilised as grass combined with plantations for the provision of fuel and fodder : the Forest Department in the United Provinces have planted up, at but little cost, some thousands of acres in the Saharanpur and Bahraich districts and hope to obtain about 600 tons of green leaf fodder and 1,500 tons of fire wood per square mile of plantation per annum.

Sir C. G. Trevor's Committee recommended the formation in every Province of a Standing Fodder and Grazing Committee composed of officers deputed by the Forest and Revenue Departments and an Animal Husbandry officer to study these waste soils and advise as to their development. I entirely agree and would only recommend the addition of an agricultural officer having special knowledge of soils and who could suggest suitable fodder crops for any areas where they might grow.

Besides these " cultivable wastes " there are better grazing lands some of which are in private hands, and others more or less communal.

So long as the grazing lands remain open and unfenced it is difficult to effect much improvement : the animals wander freely and can eat out the best of the herbage, leaving it no opportunity to recover.

Enclosure and rotational grazing are the most effective improvements. Division of the area into fields which are grazed one by one in rotation gives the vegetation a chance to recover, and, there being more of it, the animals need not wander far in search of food, and some of the enclosed grass may be spared for conversion into hay.

The chief practical difficulty is of course the problem of fencing : cattle-proof fences of the ordinary kind being costly (1).

The time at which the animals are allowed to graze the herbage is important : indeed in England one can change the character of the herbage entirely by merely altering the incidence of the grazing : heavy autumn grazing changing the flora in a different direction to the change produced by heavy spring grazing.

Dr. Burns' investigations on the improvement of grasslands in Bombay are well-known (2).

(1) An alternative and much cheaper method might succeed : a single strand of barbed wire in circuit with small induction coil charged by an ordinary motor car battery suffices to keep the tame British cattle from straying : they greatly dislike the slight shock received when they explore the wire with their noses.

(2) Pusa Memoirs, Bot, Series, 1925, Vol. 14 and 1929, Vol. 16 ; Bombay Department of Agriculture Bulletin.

Further investigations are needed on the manuring of the land : open grazing lands in the dry parts of Australia and New Zealand have greatly benefited from phosphatic fertilizer. An experiment on these lines is being organised on the *barani* grazing area of the Hissar Farm in the Punjab. Heavily grazed enclosed land may respond to manurial treatment where the open land did not.

Closely associated with manuring is the provision of " licks " to give the animals any mineral nutrients that may be deficient in the herbage. Chemical analysis of the herbage from various hill pastures is being carried out at Lyallpur and other centres (page 133).

Enclosed land can also be improved by reseeding with mixtures of grasses and leguminous plants as has been done in the Central Provinces, and this gives an opportunity of introducing better or more drought resistant grasses. Some excellent work on this subject is being done by Dr. Pole Evans of Pretoria, who has searched the highlands of East Africa and the deserts of South-West Africa for drought resistant grasses and found a family of Wooly Finger grasses some members of which, notably *Digitaria Seriata* and *Digitaria Pentzii* are proving remarkably successful. It is desirable to experiment with these and with other drought resistant grasses. I gather from Mr. C. C. Calder of the Botanic Gardens, Calcutta, that certain Central American plants thrive very well in India, evidently finding the conditions suitable, and some of the grasses might prove useful as fodder. Introduction of exotic species, however, demands very great care and close botanical supervision.

Some of the indigenous grasses are very good : lists of the kinds best suited for hay are given in the Military Grass Farm Manual. More experiments should be made on the indigenous grasses at the Stations : a few selections are being made at Hebbal Farm, Bangalore and at the Experimental Farm, Nagpur, and this type of work should be extended ; there may be possibilities of considerable improvement.

The grazing lands around the village may in the monsoon give more vegetation than can be consumed at the time. Ensilage seems the best way of utilising this temporary excess and experiments should be undertaken to find the relative advantages of pit and of stack silage ; and of one cut of full grown herbage as against two cuts of less mature material. The effect of molasses on the making of silage should be examined.

Fodder Crops.

A wider introduction of fodder crops into Indian agriculture would probably effect great improvement in yields and in total output. More food for the animals would mean more manure and enhanced fertility of the soil. This was the prime factor in the improvement of British agriculture and the additional yields of grain more than compensated for the area taken from grain and put into fodder crops. Leguminous fodder crops in addition to increasing the quantity of farmyard manure also enrich the ground on which they grow ; they cannot usually be fed alone, however, and generally are mixed with non-leguminous crops.

In the Punjab considerable areas of fodder crops are grown without irrigation but in many parts of India this is not possible, and water must be supplied ; considerable quantities of food per acre can then be obtained. Berseem (*Trifolium Alexandrinum*) is one of the best fodder crops : it is a native of Egypt but it grows well in Northern India (North-West Frontier Province, Sind, Punjab, United Provinces, Bihar) under irrigation. Some striking results have been obtained with it in Sind (page 138) : it can be sown in the cotton just after the last picking. One of its great advantages is that it increases the fertility of the land on which it grows and hence it furnishes not only its own weight of food but additional yield of the succeeding crops. In Sind it has the added advantage of being Kalar resistant and useful in the reclamation of saline land. Mr. C. H. Parr of the Meerut division has experimented with berseem as a catch crop, feeding it to buffaloes for milk and obtaining also additional yield of the succeeding crops : this type of work should be extended. One difficulty in regard to berseem is the supply of seed which was reported to me to be both insufficient and bad owing to a mixture of weed seeds. Peshawar is at present the chief source, but a wider area of supply could no doubt be developed. Two local leguminous crops seem to deserve further investigation and selection : Sengi (*Mellilotus parviflora*) and Shaftal (*Trifolium resupintum*) or Persian clover.

Various exotic grasses grow well as fodder crops : Napier grass (*Pennisetum purpureum*), Guinea grass, Sudan grass (*Andropogon sorghum*), var. *Sudanensis* : under irrigation and manuring these can give several cuts a year to be fed green or made into hay or silage.

One of the Australian grasses, *Paspalum dilatatum*, has given promising results in Assam, and it would be worth while trying a successful Australian clover, subterranean clover.

The fact that fodder crops are used to supplement to grass probably explains why some of the best developed cattle in India are produced in dry areas where the growth of grass is sparse. The cattle reared on coarse rank grass in the wetter parts of India are of poor quality and of little use either for milk or for work.

In the event of a dairy industry developing there would be great scope for these fodder crops.

Fodder trees.

If any extensive planting of the " cultivable waste " were done it would be necessary to study the fodder trees more fully so as to know which to choose for the plantations. In addition to the native trees the Carob tree, cultivated in Palestine, a leguminous tree providing pods of nutritious seed, might be worth investigation.

Tobacco.

One of the most striking changes in personal habits since the war has been the increased smoking of tobacco. Large quantities are grown in India, most of it for home consumption, but an increasing amount, of increasingly good quality, is exported. Tobacco has many advantages as a cash crop and its cultivation deserves cautious encouragement.

It grows best under conditions of good natural rainfall, and there is no evidence that it would develop any high degree of quality under irrigation. The most important tobacco growing area in India is the Guntur district of Madras where some 120,000 acres of cigarette tobacco were grown in 1936, of which 42,000 acres were Virginia tobacco of the best quality—mostly Harrison's Special. Tobacco intended for the higher quality markets is flue cured, most of this is Virginian :—

Production of Flue cured tobacco.

	Million lb.
Flue cured Virginia tobacco	29
Flue cured country tobacco	3·6
Total, Guntur district	32·6

The total production of tobacco of all grades in India in 1936 was 1643 million lb. but of this only about 110 million lb. were up to export quality, and only about 29 million lb. were in fact exported : the United Kingdom took nearly half. The total quantity exported has not varied much in the last ten years and of course the values are less than they were, but so far as the United Kingdom is concerned there has been a shift in the direction of higher quality, so that not only are its imports higher but also the values :—

	Tobacco.		Total exports.	
	To all Countries.		To United Kingdom.	
	lb.	£	lb.	£
Average 3 years.	(thousands).	(thousands).	(thousands).	(thousands).
1927-28 to 1929-30 ..	30,071	855	9,977	288
1933-34 to 1935-36 ..	28,978	670	11,460	320

Both dark tobacco and cigarette tobacco are exported from India to England, the latter in increasing quantities :—

Imports into the U. K.	Million lb.		
	1934.	1935.	1936.
Indian dark tobaccos	5	6·4	6·2
Flue cured Virginia	4·8	5·2	7·5
Total ..	9·8	11·6	13·7

The production of good quality tobacco requires a good deal of skill at all stages The crop has to be well grown, adequately manured, carefully harvested, dried and cured in flue barns. A cultivator who can produce tobacco well is equal to any type of crop production. It is unfortunate that the regions of good tobacco production are so restricted, for a leaven of successful tobacco growers would go far to raise the level of agricultural education in the country. I was informed by representatives of the fertilizer industry that the Guntur tobacco growers have a better appreciation of the proper use of fertilizers than almost any other Indian cultivators. The Council has organised a comprehensive scheme of research on the subject the results of which cannot fail to be of value.

These investigations should be done in consultation with the buyers' experts. The principal purchasers are said to be the Indian Tobacco leaf Development Company, a subsidiary of Imperial Tobacco Co., who are in a position to give information about the buyers' requirements.

CHAPTER 3.

Factors improving the yields of crops.

Seven great factors capable of improving the yield of crops in *India are* :—

(1) Better varieties of crops.

(2) Better control of pests and diseases.

(3) Better control of water supply for crops.

(4) Prevention of soil erosion.

(5) Better use of manures and fertilizers.

(6) Better implements and cultivations.

(7) Better systems of cropping, in particular better rotations and the use of more fodder crops with the view of obtaining more farmyard manure.

(1) Better varieties.

As already stated, the search for better varieties is being vigorously and effectively pushed forward. The work has reached a stage when persons selected for new appointments in connection with it should be expected to have had specialised genetical and cytological training in addition to a sound scientific education, but this presents no difficulty. A cytological assistant has been appointed to the Sugar Cane Station, Coimbatore, and a good case has been presented for appointing another at Lyallpur in connection with the investigations on the very difficult group of Brassica oilseeds. The results of this cytological collaboration should be closely watched and if it appears that the work is aided thereby it can be extended to other crops.

The whole of the plant breeding work in India would gain if it could be associated with a first class geneticist of sufficient scientific distinction to win the respect of the officers in charge of the various crops. They are, however, doing their work so well that no one of less than the recognised first rank would be of any use.

In spite of their merit the new varieties are not as yet in general cultivation. It is impossible to say with certainty what proportions they occupy of the areas sown, but the figures are greater for the

cash crops than for the food crops. So far as I have been able to obtain them they are as follows :—

TABLE 15.

Approximate Proportion of area sown with improved seed.

Crop.	Total acreage Million acres.	Acreage under improved seed. Million acres.	Percentage.
Sugar Cane	4·00	3·22	80·0
Jute	2·18	1·12	50·0
Wheat	33·61	6·96	20·6
Cotton	26·00	5·04	19·2
Rice	83·43	3·58	4·3
Ground Nuts ..	5·86	0·22	3·4
Millets	38·69*	0·34†	Not calculated as figures are incomplete.
Gram	16·90	0·33†	

*Including Juar, Bajra and Ragi only.

†*Not separately reported by some provinces.*

Probably the chief reason for the slow adoption of the improved varieties is the difficulty of obtaining adequate supplies of certified seed, which in turn may be attributed to the lack of an honest and effective seed trade to take up the new varieties, to multiply them and distribute them to the cultivators at a reasonable price.

At present this work is left to the Agricultural Departments which are already overburdened with duties. Several methods have been devised, *e.g.*, in the United Provinces by Mr. P. B. Richards, and in Sind by Mr. W. J. Jenkins : these deserve close attention.

The Council should at an early date enquire into the methods of seed distribution with a view to discovering what improvements might be adopted, and it should consider the advisability of setting up some central organisation in each Province for the multiplication and distribution of seed of approved varieties of crops, sets of sugar cane, named varieties of fruit trees, etc.

(2) CONTROL OF INSECT PESTS AND PLANT DISEASES.

Insect pests and plant diseases cause serious losses to Indian agriculture and the trouble is likely to become worse with every improvement in transport. If a pest or disease appears on a crop in any part of the world it is only a matter of time before it has travelled to all other parts where the crop is grown, and although quarantine regulations may cause delay they are rarely effective enough to keep the pest out altogether.

Conditions in sugar cane fields are particularly favourable to insect and fungus life and large numbers of pests are known to occur there : only few are serious, but they do great damage. Among the worst at the present time are the borers, which reduce not only the yield but also the percentage of saleable cane and its milling value, and the trouble seems to be increasing. An instructive survey of the cane delivered to five factories in Bihar(1) shows that 37 to 55 per cent. of the cane was infested in 1937 as against 20—30 per cent. in 1935. More surveys of this kind are needed so as to show which pests are increasing and which, if any, are decreasing.

The increase in area under sugar cane is almost certain to be accompanied by an increase in insect and fungus attack and an accumulation of the pests, and the problems concerned are more serious than those of cultivation and manuring, because they are less definite and more spasmodic in their incidence. In particular more information is wanted as to the extent to which ratooning, which has obvious economic advantages, is sufficiently favourable to the carrying over of pests and diseases to cause serious difficulties later on. Also it is important to ascertain the effects on subsequent pest and disease attack, of destroying the tops, leaves, and trash immediately the crop is harvested : or of making them into compost, or simply leaving them to be disposed of at some later date. The information should be collected by means of surveys, the results of which should be worked up at the Imperial Research Institute.

Diseases are, as a rule, best studied by a group of workers keeping to one crop : *e.g.*, a cotton group : a sugar cane group, etc. : the organisation of research work on a crop basis adopted by the Council is a very sound procedure. Much of the work, usually the most important part, must be carried out in the regions where the diseases occur : arrangements for co-operation must always exist between the Central body and the Provincial Departments and the Council should always be prepared to send, if possible a research officer to a station where a pest or disease is doing serious damage, both with the purpose of obtaining more information about it and of helping in its control. Co-ordinating investigations and detailed studies of collected records should be carried out by the Imperial Research Institute at Delhi.

It is very desirable to produce at an early date a handbook giving the various diseases of sugar cane and describing the methods found in India and other countries to be effective against them.

Three methods for control are in general use :—

(1) Avoiding the trouble altogether by finding resistant varieties of crops ;

(2) Obviating the attack of the pest by some change in soil conditions or in methods of cultivation, *e.g.*, by better drainage, by earlier or later sowing ;

(3) Destroying the insect or fungus by chemical or biological means.

---

(1) Carried out by Dr. L. H. Haldane, Chief Chemist to Messrs. Begg, Sutherland and Co.

The search for resistant varieties is going on vigorously : *e.g.*, for rust resistant wheat by Professor Mehta : for varieties of linseed resistant to wilt. The method is very useful but not final because the resistance of the plant may break down and the insect—though not as a rule the fungus—may change its habits. The usual method of selection is to grow varieties side by side and observe which are least attacked. Escape from attack, however, does not necessarily imply actual resistance : it means only that some other varieties are preferred ; it does not show that the so-called resistant variety would escape attack if grown by itself. The search therefore must be continuous, and when a "resistant variety" comes into cultivation selection must still continue in hopes of finding a more resistant form. The final stage, immunity, is hardly likely to be reached : true immunity is very rare.

The causes of resistance and immunity are of great scientific interest and would form a very suitable theme for the main work of a large University Department but they are outside the scope of an agricultural experiment station.

The obviation of insect and fungus attack by changes in methods of cultivation or in soil conditions is in some cases very effective. A good instance of work on these lines is at the Tocklai Tea Research Station where Mr. Andrews has followed in detail the waxing and the waning of attack of certain important insects and so discovered the conditions favourable and unfavourable to their multiplication. Mr. P. B. Richards is attacking the problem of sugar cane pests in the United Provinces in a similar way : he lays special stress on the education of the cultivator to ensure that only suitable soil is chosen for the growth of the cane and that proper rotations and good agricultural methods are adopted. While entomologists cannot prevent insect attacks they can estimate the relative intensities of attack under different conditions and so guide the agriculturist in the choice of practical measures for control.

The destruction of the pest or fungus by chemical means is suitable only for fruit or vegetables, but in some instances it is the only practicable method, and spraying is being taken up by certain groups of cultivators. The making up of the spray mixture always presents some difficulty, particularly when poisonous substances are used, and the search for vegetable insecticides now being made by the Agricultural Department in Mysore and by the Forestry Department at Dehra Dun is entirely commendable. I suggest on page 196 certain modifications of the programme for the purpose of bringing the direct biological tests more into prominence, and of ascertaining whether the selected plants lose their value on cultivation. It is important to have available in India safe effective vegetable insecticides.

Biological control.

The insect pests that prey upon crops are themselves preyed upon by smaller insects and it has long been realised that these parasites might be utilised for keeping them in check. The possibility is extremely attractive : in principle one has only to find the parasite, breed it in sufficient numbers and let it loose in the

field, when it proceeds to prey upon the pest, reducing it to impotence. A vast amount of experimental work has been done on the subject by some of the ablest entomologists in the world, and some striking successes have been obtained, notably in the Hawaiian islands, by introducing the parasites of a pest, but elsewhere there have been numerous failures.

In St. Kitts the sugar cane borer appears to have been considerably reduced by the parasite *Lixophaga diatraeae,* and pests of other crops have been successfully controlled in New Zealand, California and Cuba. In Canada the larch saw fly and another saw fly (*Diprion frutetorum*), the oriental Peach Moth, and, on the Pacific slope, the Hawthorn Scale (*Lecanium coryli*), all accidentally introduced from other countries, have been successfully controlled by parasites.

On the other hand in the United States the Gypsey Moth and the European corn borer, both introduced pests, remain major pests even after years of work and the expenditure of millions of dollars on introducing parasites. And in Mauritius the parasites *Tiphia paralella* introduced from Barbadoes, while reducing the intensity of attack of the root pest of sugar cane (*Phytalus Smithi*), still left it a serious problem.

Generally speaking the successes have been obtained in islands or, if on Continents, with introduced pests. I have failed to find any good instance of a native pest being satisfactorily controlled by an introduced parasite in a Continental region. The problem of the sugar cane borer in India falls within this last category : it is an indigenous pest of an indigenous crop and India is a Continental region. (1)

Of course this does not mean that no success ever will be attained, but simply that success cannot be confidently counted upon, and the work if begun must be continued over a period of years without expecting speedy results ; meanwhile efforts in other directions should continue.

No good direct method of control for borers, however, is known and in view of the heavy loss they cause it is very desirable that an expert should visit India and report on the question whether biological control should be attempted ; if so, on what lines, and whether any other methods would offer any better chance of success.

Control of insect and fungus pests is not simply a matter of scientific investigation : it involves difficult educational and administrative problems. Some degree of compulsion is necessary ; and since there must be speedy and uniform action it is essential to have some central control in addition to that exercised by the Provincial Departments. Pests spread regardless of political boundaries and rapid action against them may have to be taken.

(1) A full account of the present position of the subject is given in a recent book " The Biological Control of Insects ", Harvey L. Sweetman, Cornstock, Pub. Co., Ithaca, N. Y., 1936.

Accounts of outstanding successes are given by T. H. C. Taylor, " The Biological Control of an Insect in Fiji ", Imp. Inst., Entom., 1937. Also : S. D. Tothill, T. H. C. Taylor and R. W. Paine, " The Coconut Moli in Fiji ", Imp. Inst., Entom., 1930.

Locusts bred in Baluchistan fly into Sind and Rajputana and breed again ; they may fly into the Punjab, United Provinces and Bengal and breed, and the hoppers may do great damage. Control in these provinces, however, is cumbersome and expensive ; it should if possible be effected at an earlier stage. The rust of wheat comes from the hills of Nepal and the Nilgiris ; its minute spores blow down into the plains where they greatly damage the wheat. But control is possible only in the hills. The San Jose scale, a deadly foreign pest of fruit trees, got into Kashmir where energetic steps should at once have been taken against it : it is now spreading through Northern India. These pests often do more harm in the Province to which they pass than in that from which they have come and it is of course far more economical to control them before they arrive than to wait till they are in.

Two methods seem suitable for obtaining the technical information needed by the Central Control body :—

(1) The Council could continue to make grants as at present for studying plant pests and diseases in the Provinces ; it could organise teams of specialists for particular crops, *e.g.*, cotton, sugar cane, etc., and it could arrange for the Imperial Research Institute to co-ordinate the results and to collect information showing whether the diseases and pests are increasing or decreasing. When the necessity for general action seemed indicated the Council could call together their experts and those of the Provinces concerned to draw up a statement showing what steps should be taken to limit the damage done.

(2) Alternatively the Council could hand over the study of pests and diseases to the Imperial Research Institute, leaving that body to keep touch with the Provinces and to draw up from time to time statements showing what action should be taken in regard to particular pests or diseases.

In view of the circumstances that pests and diseases have to be studied in the areas where they occur it seems better to adopt the first of these alternatives and to keep the technical problems in the hands of the Council but using the Research Institute as the agency for collecting and collating the information accumulated.

In any case executive action in regard to pest and disease control should be entirely out of the hands of the Council. The Central Government should include it with infectious animal and human diseases, as requiring on occasion more general measures on uniform lines than is possible for the Provincial Governments to adopt.

The advice of the Council can, however, quite properly be sought by the Government as to the measures to be taken.

Weed control.

Various weeds are spreading and need serious attention : experimental work is required in the first instance to discover suitable control measures ; and then administrative action to see that the

prescribed methods are properly carried out. Among the worst weeds I saw were the water hyacinth, lantana, Kans grass, and, in Mysore, Touch-me-not (*Mimosa pudica*).

(3) THE BETTER CONTROL OF WATER SUPPLY FOR THE CROPS.

The water supply to the crops is of supreme importance in Indian agriculture and I recommend that the work in this direction should be strengthened.

Two types of problems are involved : dry farming and irrigation.

The dry farming problems are studied at a group of stations in Central India respectively under the Bombay, Hyderabad and Madras Governments. The fact that they are all engaged on one co-ordinated scheme in spite of the diversity of their forms of administration is a striking tribute to the unifying influence of the Council's activities.

The work would gain considerably if a good soil physicist could be brought into it and also an engineer, in view of the close association of dry farming with soil erosion. The possibility should be considered of linking the work of these Stations not only with the Poona Agricultural College as at present but also with the Bombay Irrigation Research Station, which would mean of course a widening of the scope of the latter. The needs are two fold : better ways of satisfying the requirements of the present approved dry farming methods ; and a fresh set of ideas on the subject. The workers at present are rather isolated, and if they could form part of a larger group their chances of finding new methods and ideas would be increased.

An All-India Irrigation Research Station.

The development of irrigation is one of the most remarkable features of modern India. Three sources of water are used :—

(1) canals from the great rivers—either snow fed rivers, or rain fed, and therefore requiring storage arrangements ;

(2) wells from the underground supplies in the plains ;

(3) tanks filled by rain or streams trained down into them.

The area now irrigated is very large. Out of 227 million acres sown in British India in 1934-35, 50.5 million were irrigated ; practically half (26 million acres) from canals, and one quarter (12.5 million acres) from wells ; further schemes are being discussed. A striking development is the combination of irrigation works with the generation of electricity which promises to effect marked changes in the life of the larger villages and smaller town.(1)

(1) The Meerut tube well scheme under the supervision of Sir William Stampe is a notable example of a well planned effort to combine water supply with electricity and with such amenities as bathing and washing facilities.

The supplying of water to the cultivator is the business of the irrigation engineer, and is usually well done in India. Two of the large provinces where irrigation is important, the Punjab and Bombay,(1) have Research organisations and other provinces have Research Officers who, however, are not infrequently charged with other duties also.

But the supplying of the water is only a part of the problem. A much more difficult matter is to use it advantageously so as to ensure permanent benefit to the district, and repayment of the heavy capital costs. When a great dam or barrage has been opened with much ceremony and flourish of trumpets it must always be remembered that the problems still remaining are greater than those already overcome because they are more continuous, more subtle, and much less under the control of the experimenter.

Three great groups of agricultural problems arise.

(1) Selection or if necessary production of new varieties of crops suited to the new conditions. New selections and hybrids are produced in many parts of India and interchange should be freely arranged between the various staffs concerned. The final selection must necessarily be made in the region where the crop is to be grown.

(2) The designing of new cropping schemes. Usually the water supply is not entirely continuous but more is available at some seasons than at others. The cropping has to be so arranged that the best use can be made of the water and of the man and bullock labour available. Much more attention should be paid to this troublesome problem of arranging a sequence of crops at once profitable to the grower and permitting the best use to be made of the water. The potential improvement is shown by the fact that even now some cultivators succeed in making the water go much further than others : some of the Punjab sequences are admirable : while some of the larger cultivators have worked out methods that deserve detailed study and trial elsewhere.

In canal irrigation the water must be taken when it is given and the cropping scheme adjusted to the supply available. In planning a new canal irrigation project, therefore, the proposed cropping scheme should be as fully and as carefully considered as the engineering details.

Where the water is supplied from tube wells greater control of the supply on the individual farms is possible, and therefore greater flexibility in the cropping scheme. Another set of problems then arises : the best times to supply the water to each crop and the optimum quantities to give.

These problems are fairly straightforward and present no special peculiarity.

The soil problems, however, are much more difficult, especially in regions of canal irrigation. Waterlogging and neutral salts can be dealt with, though the treatment may be very costly, but behind every large irrigation scheme there lurks the spectre of the alkali

(1) Irrigation is chiefly by canals in the Punjab and from tanks in Bombay. The Bombay schemes are largely concerned with prevention of famine.

problem, for which in its final stages no economic solution has yet been found. Well designed experiments would no doubt suggest methods of dealing with the incipient stages when action is possible, and these should certainly be undertaken as early as possible. Constant watch should also be maintained to ascertain whether the salted and waterlogged areas are increasing or decreasing. Photographic aerial surveys would probably be the speediest and most effective means of doing this.

It may be laid down as an absolute rule that no irrigation scheme should ever be carried out until a proper soil survey of the region has been made. Areas containing salt or liable to serious water-logging should only be brought into the scheme after consideration. This may necessitate a survey of the floor of the region, as described on page 128. A good preliminary survey reduces the risk of trouble to a minimum : but it is always there and on some of the existing schemes it is considerable.

All the various problems concerned are being studied at some or other of the research Institutions, but the work is scattered, it is uneven in quality and in scale, and it lacks unified direction. I strongly recommend the establishment of a Central Irrigation Research Station to undertake investigations on all agricultural problems associated with irrigation, and to supervise or be closely linked up with other irrigation investigations supported by the Council. The Station must be situated in the heart of a large irrigated area : the Punjab or Sind are obvious possibilities, probably the Punjab would be better as it could there be closely associated with the existing Institution at Lahore and with the college at Lyallpur.

But I cannot too strongly emphasise the difficulty of the work and the necessity for choosing the staff solely on the ground of their ability to do it. Suitable men are extremely scarce, and any restriction on the choice is likely to prove fatal to the scheme.

The Lahore Institute would remain as at present the centre for engineering research. It is so well staffed that it could probably widen its scope and undertake research on the surfacing of earth roads in rural districts, a subject which is not so remote from its present work as might at first sight appear. I suggest that the Council consider the advisability of discussing this possibility with the Irrigation Department.

(4) Prevention of soil erosion.

In natural conditions the soil is usually covered with a growth of vegetation which protects it against the disintegrating effects of wind and rain and so enables it to remain permanently in position. In general the higher the rainfall the denser the cover, and in wet regions where forest or grassland develops well the protection is very effective.

As soon, however, as the protecting cover is removed the soil is liable to be carried away by wind or by water—usually in India by water—and damage is caused in three distinct ways :—

(1) the removal of the soil makes the affected area useless and it may lead to the scooping out of great ravines ;

(2) the soil that is washed away may injure the land on which it is deposited, or it may silt up canals and rivers, and so lead to the washing away of river banks or even to floods ;

(3) while the vegetation cover is intact the rain water soaks in, accumulating as underground stores or breaking out in springs and steadily flowing streams. With the removal of the vegetation cover it is no longer able to do this and instead runs off as flood water. The stores of underground water are therefore no longer replenished : wells, springs and little streams may all run dry. Floods take their place.

The removal of the vegetation cover usually results from an increase in numbers of human beings or of animals. Erosion is particularly liable to happen on sloping ground either in moderately wet or in dry regions. The usual causes of removal are :—

(1) Deforestation.

(2) Heavy grazing.

(3) Seasonal concentration of migrant flocks on the alpine migration routes.

(4) Ploughing or clean cultivation of sloping land.

(5) Fire, as in jhuming.

The forest officers are so thoroughly familiar with the dangers of deforestation that they are not likely to allow improper cutting of timber where they have authority to stop it. Uncontrolled grazing, however, is a much more serious matter because the mischief is not at first obvious : it may become a grave danger and wider powers of control should be given to the officers in the interests of the villagers themselves.(1) Goats are in general regarded as the most destructive of all animals, ruining vegetation and soil alike, but buffaloes and cattle may be as bad or worse, especially in damaging trees. Rotational grazing can be so managed as to provide at least as much fodder as unrestricted grazing, without deterioration of herbage or erosion of soil.

Cultivating up and down the slope of a hill, or setting the lines of crops, *e.g.*, potatoes in this direction, renders the soil liable to very serious erosion. So also does the clean cultivation of tea or coffee plantations on sloping ground. Green cover crops are, from this point of view, much better ; they can be dug in for manure and so help the bushes to grow till they themselves cover the ground.

Jhuming as practised in Assam is liable to lead to erosion, and experiments could usefully be undertaken to reduce the risk.

Erosion is not confined to regions of high rainfall : it occurs also in dry regions. The rainfall when it comes is apt to be torrential and the protecting cover is only light so that once erosion begins it may become serious.

---

(1) Sir C. G. Trevor reports that in the Etawah region so good a grass cover developed after closing to grazing that erosion entirely ceased. Many other instances are on record.

Both in wet and in dry regions the remedy for erosion is based on the same principle ; the reduction of the velocity and the amount of water running off the surface. The crucial area is at the top of the slope : if water can collect here and start running down it is very difficult to check. Several methods can be adopted :—

(1) Afforestation of the top slopes : one of the surest methods where this is practicable.

(2) Putting the upper slopes into grass, or, if cropping is necessary, alternate grass and arable strips. This device has also served to prevent sheet or wind erosion. The grass affords effective protection provided excessive grazing is prohibited.

(3) Ploughing along the contour lines instead of across them.

(4) Bunding or terracing.

Bunding is in practice the most usual way of overcoming the difficulty and it has the advantage not merely of protecting the land against erosion but also of increasing the water supply to the crop.

Much bunding is already done in the erosion areas but a good deal more is necessary. In the United Provinces the construction of bunds is a regular famine relief measure ; it is indeed almost ideal for this purpose, being a capital improvement of great and permanent value.

In dry regions the tendency is for the peasants to put the bund up only at the bottom of the slope, but this is insufficient : small bunds should be set up at suitable and not too great distances ; in the North Central division of the Bombay Presidency this has been done by means of a tractor. For bunding, and more particularly for the construction of large embankments, the Bombay Agricultural Department has given advice and the Revenue Department has advanced money at moderate rates of interest in the Southern district since 1921.(1)

Cases are, however, recorded where bunding has done harm by causing the water to stand too long on the soil. Here some additional measure, such as contour ploughing, seems needed.

So far as funds have allowed, the Forestry Department has for many years been setting up embankments in the ravines within their control in the foothills of the Punjab so as to collect the silt and make approximately level surfaces on which trees can be planted. Large areas have been closed to grazing and left undisturbed in grass and some of them give revenue of as much as 16 annas per acre for grass cutting compared with 1½ annas per acre for grazing. These reclaimed areas absorb much of the rain water falling on them and so reduce greatly the violence of the floods. This of course greatly benefits the plains, for the canals are no longer so badly silted up and the rivers no longer erode the fields on their banks.

Only about one-tenth of the foothill region of the Punjab, however, is under control of the Forestry Department. On this a vegetation cover is maintained, but the rest is partly under some

(1) An account of the Bombay work on the subject is given in a Report to the Crop and Soil Wing of the Board of Agriculture in 1935, p. 259.

How fertility is lost.

form of cultivation and partly used as hill grazing. No Government Department exercises much control, and mismanagement is common.

In dealing with soil erosion the need is for more action rather than more research. In spite of numerous and protracted investigations by competent workers in the United States and elsewhere it has not been found possible to discover anything more than very general relationships between erodability of soil and chemical or physical composition. The environmental factors are extremely important as also are the ways in which the soil constituents are built up into crumbs and the distribution of root residues in the soil. I see no point in spending time and money on approaching the subject from the laboratory end ; the problem is in the field and there it should be worked out.

The measurements of the amount of soil lost by erosion in India are only few and very variable : they range from 1 ton to 115 tons per acre, depending on the amount of cover and other conditions.

Protection against erosion should be a State responsibility and not left entirely to the individual. The cultivators in the critical positions may be unable or unwilling to spend money on the necessary protective works. In all Provinces where erosion is likely to occur an Erosion Conference should be held annually at which forestry, animal husbandry, and soil experts should meet the agricultural staffs and, after receiving from them reports on the districts where erosion is liable to occur, should discuss with them modes of checking or remedying it, dealing with each erosion area as a whole. The Minister should then have the power to carry out the recommendations, levying a rate on all land thus protected. The Tennessee Valley Authority in the United States is an example of the way in which a statutory body of this kind functions. It is achieving results hitherto regarded as impossible.

(5) Better use of manures and fertilizers.

Every writer on Indian agriculture has commented on the wasteful practice of making manure into cakes and burning it, but it goes on unabated for the simple reason that no other equally useful fuel is available : the manure cakes need no cutting up, like wood ; and they burn slowly. The only way of stopping the practice is to provide an alternative supply of fuel.

The rapid and almost complete change from the old village-made lamp to the machine-produced hurricane or bracket oil lamp raises the question whether oil stoves are ever likely to come into such general use for cooking in the villages as they have in the towns. We may best leave this to the future : in the meantime the most hopeful method is to plant quick growing trees near the village, preferably on the side from which shelter would be an advantage as protection against discomfort or soil erosion.

Castor and neem cakes are also much used as manure especially for sugar cane and this is justified since they are unsuitable for feeding to live stock.

Composting of waste materials is now a recognised part of the activity both of the experiment stations and of the village improvement associations, and we may expect some addition to the manurial resources of the country as a result. I could find little direct evidence as to the fertilizer value of compost as compared with oil cakes or artificial fertilizers, but from the low content of Indian soils in nitrogen and organic carbon, averaging about 0.05 and 0.6 per cent. respectively—about one-third the values in arable soils in England—it is inferred that organic manures are greatly needed. In any case, however, composting is to be encouraged in the villages on sanitary grounds even apart from any fertilizer value.

Green manuring is included in the schemes at several of the stations and should be tried wherever paddy is grown.

Until about ten years ago there was little systematic experimental work on artificial fertilizers, the relatively small amounts used being taken almost entirely by tea growers. From 1926 onwards, however, the large fertilizer organisations dealing with India have attempted with some promise of success to develop the use of fertilizers for general agriculture : the South, I am informed, is more " fertilizer minded " than the North.

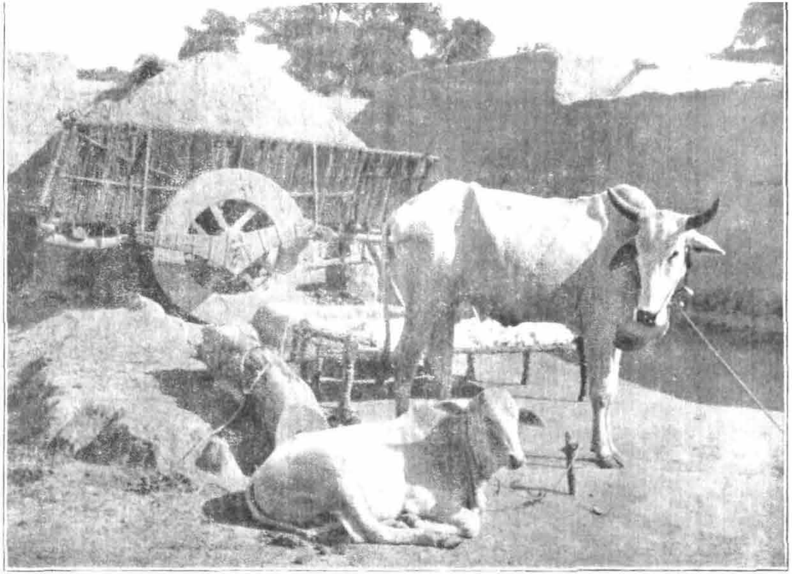
The results given by fertilizers depend almost entirely on the water supply. In regions of precarious rainfall or inadequate irrigation, artificial fertilizers usually fail and organic manures are erratic in their action. With good moisture supply artificial fertilizers are more effective. Nitrogenous fertilizers usually give the largest returns. In some of the experiments one maund of sulphate of ammonia in addition to the normal light manuring gave the following additional maunds of produce :—

55 sugar cane.	1 tea.
5 sugar.	4.5 paddy.
15 potatoes.	3 wheat.
1.2 leaf tobacco.	1.6 seed cotton.

Concentrated organic manures, oilcakes, fish manures, hoof meal also gave good returns. Phosphatic fertilizers (superphosphate) usually acted well especially in the crystalline tracts of Peninsular India, but only when in combination with nitrogenous fertilizer. Potassic fertilizers are effective for certain special crops such as tobacco.

Little is known as to the most suitable time of application of the fertilizer : at the time of planting appears to be best except for sugar cane for which two instalments are given. Little information is available about the proportions of nitrogen, phosphorus and potassium required for different soils and crops or the proportions in which organic manure should be used.

Speaking generally the fertilizer and manurial trials at the experiment stations need to be more systematic so as to show the



The unimproved cart and cattle.

relative value of different forms of nitrogen and of different dressings per acre. They should not, however, be confined to the station but some simplified form should be tried as widely as practicable on cultivators fields and the chemist should receive samples of the soils so that he may see if any relation exists between the field results and the data given by the recognised methods of soil analysis. It would be of considerable advantage if this work could be done in association with the large fertilizer organisations who have already collected considerable information on the subject and who have a wide experience of the types of experiment possible.

Some provinces, *e.g.*, Madras have already effected a certain degree of co-operation.

(6) BETTER IMPLEMENTS AND CULTIVATION.

Considerable efforts have been made in recent years to improve the implements, but there is scope for much more work on this subject especially on the developmental side. The new implements are not always more effective than the old when these are worked in the best way possible, but they are lighter, require less labour of man and of bullocks, and they do their work more rapidly. It is difficult to over estimate the value of these advantages. Economy of bullock power means that the large cultivator need not possess so many bullocks and so can better feed his milch catle ; and speed of work means that operations can be done just when necessary, and when therefore they are most beneficial. This more rapid cultivation would be of advantage in keeping down weeds and in improving the moisture supply in dry regions.

Numerous experiments have been made in the technique of demonstrating the value of the new implements : references to some of these are made in Part II.

So far the new ploughs seem to have been taken up more rapidly than anything else. I saw various improved water lifts demonstrated but not in ordinary use. The greatest task of all, however, is the improvement of the bullock cart, at present a cause of strain on the road, the bullock and the other travellers. Ball bearings and subsidised rubber tyres are being tried, but the problem may be much diminished by the development of motor transport.

Co-operative societies where they function are probably the best means of spreading improved implements.

(7) BETTER SYSTEMS OF CROPPING.

These are discussed in Part II.

I was much impressed by some of the good sequences of crops in the Punjab and the United Provinces : experience generally is in favour of rotations rather than single cropping. Rice is of course the great difficulty : alternative crops and sequences are easier to arrange on light than on heavy soils, especially those liable to be flooded.

CHAPTER 4.

Special difficulties confronting Indian agriculture.

(1) THE ABSENCE OF AN EDUCATED CLASS FROM THE VILLAGE.

As compared with other countries India suffers specially great difficulties in the speeding up of agricultural improvements : illiteracy : debt : the inertia that comes of malnutrition and illhealth : the excessive numbers of livestock : the efforts of social customs (using the term in its widest sense) and of social structure and the fact that there are something of the order of 700,000 villages ; and it cannot be expected that these difficulties will easily be overcome.

Perhaps the most serious of all the difficulties confronting Indian agriculture is the lack of an agricultural aristocracy and of an educated agricultural middle class. Many of the great advances in Western agriculture are due to men of this type : highly competent agriculturists, rooted in the soil, with a thorough knowledge of crops and livestock and a shrewd idea of how to get the most out of their land. It is quite certain that without them the West would have been in a far poorer position than it now holds. In Great Britain an improvement effected in the experiment stations can be at once put out into practice : some large farmer is prepared to try it at his own expense as soon as he is satisfied as to its value, and he almost invariably finds some simpler or better way of using it. But these good farmers also themselves devise improvements, which are sometimes better than those of the experiment stations. Indeed the experiment stations think themselves fortunate if they can obtain yields as good as those of the best farmers, and their best hopes of success are to overcome some special difficulty or to develop alternative methods of achieving some desired end. The staffs of the experiment stations are compelled to keep in touch with practical men or they would find themselves outclassed in the struggle for agricultural improvement.

The existence of these educated class gives a social attractiveness to life in the country.

Unfortunately India has nothing corresponding with this educated class. The landowners are largely town dwellers and many of those who reside in the village are not themselves farming on any important scale. There are of course exceptions : I met some enterprising large farmers(1) and energetic Zemindars who were practising agriculture well and serving as models for the surrounding cultivators. Men of this kind deserve commendation and recognition and efforts should be made to increase their number.

Equally important is the need for increasing the number of educated farmers It is unfortunate that the colleges have been able to do so little in this direction. Perhaps the greatest difference

(1) Especially in the irrigated regions of Sind and the Punjab and also in North Bihar : a number of these are European. The tea and coffee planters are of course in a different category.

between the agricultural colleges in India and those of the West is that most of the western students go back to the land to do practical farming while the Indian agricultural graduates seek some non-practical post, where their influence on practical farming is very small. An old Hindu proverb states that agriculture is the best life and service the worst : the modern tendency is to reverse this and to rank Government service as the best life and agriculture as the worst. This explains the relatively small effects exerted by the Indian colleges on the cultivator's practice. Until good students from the agricultural colleges settle on the land as farmers the Colleges cannot be expected to exert much influence on village life. At each centre I visited I enquired how many College students were farming : occasionally figures were given to me and I enquired for names and addresses, so that I might write for information, but my letters were mostly either returned or unanswered, and in all my journeys I met only two or three college trained farmers. *Per contra*, the few young Zemindars whom I found taking pains with their farming had in general not been to an Agricultural College.

Yet the College trained farmer should be a great asset in a district : indeed one of them told me that as a non-official he had special advantages in introducing better varieties of seeds, green manure crops, proper rotation, manuring, more economical utilization of water, fruit culture, beekeeping, and co-operative marketing. He had succeeded with his farming and desired to extend the area of his land, but met with the difficulty that only common grazing land was available and the villagers objected to giving this up. It is possible that my experience was exceptional. The subject is, however, so important that an enquiry should be made as to why so few agricultural students settle on the land, and to suggest ways of increasing the numbers.

Lack of facilities is undoubtedly one reason and indeed I was informed that in Oudh some of the large landowners who are prepared to employ graduates as farm managers have no difficulty in obtaining them. But this outlet is insufficient to solve the problem.

Several experiments in land settlement are being tried. An "Auxiliary Farm" has been set up at Dadu in Sind for agricultural students who wish to take up practical farming : two men are given a holding of 32 acres for two years : they must themselves do the cultivation under the tuition of the staff. At the end of that time, however, they must find other land.

In Bombay a scheme is in operation under the Forestry Department whereby a cultivator is allotted land for a definite period of years on condition that he plants it with trees, and, at the end of his period, quits the holding. This scheme is applied to the poor landless classes but it seems possible that something on similar lines but of longer period might be set up for agricultural students.

While the settling of individual trained men in villages would be of advantage to the villagers it might be very dull for the men themselves owing to the lack of social life. An experiment made in the Punjab deserves special mention because it avoids this difficulty : it consists in settling literate young men in newly created villages.

It began in 1927 when the late Sir Fazl-i-Husain returned from a visit to Switzerland and France much impressed by the high standard of living on the small farms there ; and feeling that village life in the Punjab offered no attraction to an educated young man, he proposed to establish two model villages in the canal colony for educated young men prepared to live there, to cultivate the land themselves and to set better standards of farming and of living. This was done. Each village had 22 settlers selected by the colleges—20 from the Lahore Art Colleges, 2 from Lyallpur Agricultural College, and each settler was to have two squares of land (55½ acres). Rights of occupancy were granted after 5 years provided all conditions were fulfilled, but no proprietory rights. One square (27.8 acres) was reserved for the village site, and 3 squares to provide a common income for the village.

In 1935 the Government extended the scheme to another 60 settlers, 18 ordinary and 42 agricultural graduates. 28 retrenched agricultural assistants have also been settled.

As an inducement to better farming 2 half rectangles (12½ acres) are granted to the two cultivators who in the opinion of the Agricultural Department deserve it best ; each one holds his rectangle for 3 years.

I had the privilege of discussing these schemes with His Excellency Sir H. W. Emerson, Governor of the Punjab, who informed me that they are working well, and it seems desirable to extend them.

None of these schemes is more than a small scale preliminary trial : yet if one of them succeeded in its object there would be possibilities of considerable development. Probably the best chance of success would be in the direction of specialised farming such as dairying, fruit growing, etc.

(2) THE BURDEN OF DEBT : THE BANIA.

In many of the villages that I visited where rural uplift was being done I was shown balance sheets purporting to represent the income and expenditure of various selected families. Almost invariably there was a deficit which I was informed was made up by borrowing from the bania and this process has been going on for many years. The Central Banking Enquiry Committee of 1930 estimated the total rural indebtedness of India at roughly 900 crores (roughly £675,000,000) and the Reserve Bank considers that the figure has increased since then. Whether the debt can ever be repaid is a question that lies outside my province : I am concerned only with the effects on agricultural output.

It is freely stated that the cultivator feels so depressed by his burden of debt and he is unwilling to bestir himself to adopt new methods as he will gain no advantage therefrom. There may be something in this : on the other hand the bania would in his own interest be expected to see that the land is made to yield its utmost so as to be sure of preserving his capital and the continuity of interest payment. The bania could be, and in some districts is, a potent

factor in the introduction of seed of new varieties. In the Reserve Bank Report for 1936 he is described as playing an important and indispensible part in the economy of the countryside, and the only agency for supplying the credit necessary for farm production, co-operative societies having failed to do this. If he could be enlisted in the cause of agricultural improvement he might be able to expedite matters.

(3) THE SLOW PROGRESS OF THE CO-OPERATIVE MOVEMENT.

In view of the enormous success of co-operation in improving village life in the west, hopes were naturally entertained that similar results would follow in India and accordingly great efforts have been made to introduce it. Unfortunately it has not in general succeeded. It usually took the form of credit societies, financed from a central bank, and while these societies had no difficulty in lending the money, they were generally unable to get it back again. Money that should have been restricted to short term credit for productive purposes was used for long term and non-productive purposes and so became immobilised. A large part of it will probably have to be written off as irrecoverable. Some non-credit societies were formed, but these attracted less interest and usually had but little success.

Yet it is no fault of the system : the conditions were not quite suitable. The outstanding instance of success in co-operation is Denmark, a land of small farmers : and it has given them a standard of living that is the envy of the civilised world. Four essential conditions of success are all present in Denmark :—

(1) The village population is homogeneous : there is nothing corresponding with the caste distinctions ;

(2) The cultivators are all literate ;

(3) From the outset People's High Schools were set up where the cultivators were taught better living, both in the home and the village, and where ideas of corporate responsibility in village and national life were inculcated.

(4) The Co-operative Societies are mostly trading societies, taking over the produce from the cultivator, working it up into marketable form and selling it for him. Also they supply him with all materials for use in the home and on the farm. They are mainly financed by the local savings institutes and banks, and the members are jointly and severally liable for the loan. In their capacity of depositors at the local savings bank the members of the Co-operative Societies themselves provide a substantial part of the funds : it is their own money that is lent to members, and in consequence each borrower feels himself under the necessity of repayment.

Unfortunately none of these conditions is satisfied in India and so long as this is so the Co-operative movement is under great

difficulties. Something has, however, been achieved and the case is by no means hopeless. A certain measure of success has been obtained in the Punjab as a result of strict official supervision and in the Bombay Presidency where a number of public spirited business men took an interest in the Societies and saw that they were kept on sound lines. The Bombay Provincial Co-operative Bank is under the guidance of Sir Chunilal V. Mehta ant Mr. V. L. Mehta, and some of the non-credit societies have succeeded, notably the Cotton Sales Societies. I was informed also that the Visva-Bharati Societies are working satisfactorily ; here the leadership is from Sriniketan. So far as one can see there is still some chance for the co-operative movement provided strong external management is available and the credit activities can be associated with a thrift movement, the village savings going in to the society. Probably these conditions are only rarely obtainable(1), and excepting where, as in Bombay and the Punjab, a firm business directorate takes control, it seems unlikely that much can be expected from co-operative enterprises.

(4) THE FRAGMENTATION AND SCATTERING OF HOLDINGS.

Another very serious weakness in Indian agriculture is the fragmentation and scattering of holdings. The laws of inheritance lead to numerous ownerships and thus tend to make the holdings small, and custom scatters them over a wide range so that a cultivator may lose considerable time in going from one of his plots to another. Consolidation of the scattered holdings into one piece is extremely desirable, but the difficulties are very great. The problem is not peculiar in India : other countries have had to solve it but it has never been easy. In England consolidation was effected in the 17th and 18th centuries but only after serious trouble. In Poland it is being brought about now but with much objection from the peasantry. But it has to be done. Some officers appear to be more successful than others in persuading the cultivators to agree to exchange of land : men like this should be kept at the work and not transferred to other duties.

Special mention must be made of the good work being done by the Punjab Co-operative Land Consolidation Societies.

Where consolidation of holdings cannot be achieved it may be possible to carry out the next best improvement and consolidate the cropping, straightening also the boundaries. This has been done in the tube well irrigation districts of the United Provinces (Meerut Division) and cropping has been greatly facilitated in consequence.

The fragmentation of holdings, however, is a more deep-seated matter and may be incapable of remedy. Yet unless some solution is found the rate of progress must be extremely slow.

---

(1) A good discussion of the position of Co-operation in India is contained in the Report of the Reserve Bank of India, Agricultural Credit Department, 1936.

Subinfeudation.—In the premanently settled districts another difficulty arises. The tenant does not hold his land direct from the landlord who pays revenue to the Government : in between these may be a long chain of intermediate holders, each of whom takes a little profit as his share.(1) It is not easy to estimate the effects on agriculture of a series of rent receivers who feel no responsibility either to the land or the tenant.

(5) THE LACK OF TECHNICAL EDUCATION FOR THE CHILDREN AND YOUNG PEOPLE.

The school garden is widely recognised as the best way of imparting technical knowledge to young people in the villages. A school without a garden is very apt to become an agency for taking young people out of the villages : with a garden it becomes a means of helping them to improve their life there. A few schools have gardens and at the Lyallpur College I saw a group of rural teachers working in the College garden with a view to introducing new material into their own courses. But in the main the schools are without gardens and it should be part of the rural uplift movement to establish one wherever this may be possible.

(6) THE LACK OF SUBSIDIARY INDUSTRIES.

The cultivator frequently cannot maintain himself and his family on the proceeds of his farming. He must either borrow or take on other work. During long periods of the year he has ample time for this, his farming labours being very unevenly distributed over the different months. In some places he may be able to earn money by carting, but this is bound to become more precarious as motor transport develops. Casual labour on the roads or in towns is also possible but a much better way if it could be developed would be the development of subsidiary industries in the village. The great difficulty is the marketing of the produce and I confess I see no way of overcoming this : outside of the village itself the demand for village-made things is largely sentimental. Agencies that make an appeal deeper than that of the salesman, such as the Visva-Bharati or Dyal Bagh, are able to keep their groups going, but in the ordinary way of business village industries cannot easily stand up against mass production. The solution of the problem is really in the hands of the women of India, for if they insisted on purchasing village-made articles the whole difficulty would disappear. The Women's Council of Bombay have, I understand, adopted this line of action.

There is, however, an important exception. The hand-loom industry is widespread and vigorous and appears to be extending, though not as rapidly as the power loom industry of the mills. Both

---

(1) For a remarkable example, see the Final Report on the Survey and Settlement Operation in the Bakerganj district, 1900—1908. In this district there are normally 8 and sometimes as many as 20 intermediate holders.

home and export trades seem to be well organised. The figures are :—

	Handlooms Millions of yards[1] *Cotton cloth.*	Mills Millions of yarns *Piece goods.*
1930-31	1,390	2,561
1931-32	1,590	2,990
1932-33	1,700	3,170
1933-34	1,440	2,945
1934-35	*1,460*	*3,397*
1935-36	1,840 (provisional)	3,567 (provisional)

Another village industry, though much more localised is lac : this also is said to be well organised.

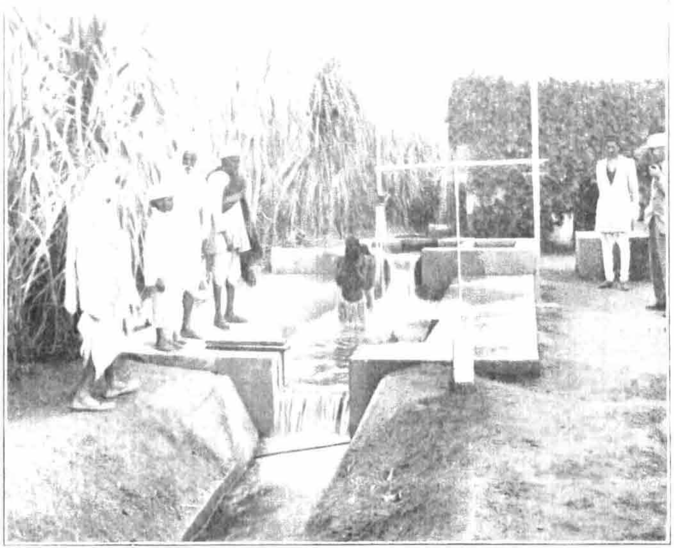
Poultry keeping is a promising way of supplementing the earnings from the holding. I heard good accounts of the work done by Mr. A. E. Slater, of the Mission Poultry Farm, Etah, U. P., who informed me that interest in poultry keeping is growing ; the demand for good poultry is increasing, and more Hindus are eating eggs than formerly. He thinks there are good prospects of success for poultry in the villages of the United Provinces. The success of poultry keeping turns on the marketing where transport facilities exist or could be created there would be the possibility of setting up of collecting stations such as the one organised by Dr. Hatch at Martandam, Travancore.

Beekeeping also offers possibilities which, however, are probably somewhat limited. It appears to be more promising in the hills than in the plains : *e.g.*, in the submontane region south of the Himalayas running from Assam to the northwest frontier ; also in the Nilgiris. It generally goes well with fruit culture. Several of the Provincial Entomologists and others are studying bees.

(7) The Lack of Leadership in the Villages.

Many of these difficulties would automatically disappear if there were effective leadership in the village ; one sees fewer signs of them in those villages—unfortunately few in number—where the chief owner is also resident and actively interested in the development of the place. Mr. Darling quotes Sir Daniel Hamilton in the Sunderbans as an example of a landlord who organises for his tenants : he has formed them—they number several hundreds—into credit and marketing co-operative societies, the latter being authorised to pay to the former whatever the member owes. A similar lead could be given in other regions where they are large landowners provided they would devote the necessary time and trouble to the work. The village panchayat would be a means of carrying through any agreed proposals, and under an effective leader could render

(1) From the method of calculation adopted, which is based on yarn produced in mills and not exported or woven in factories, it is probable that the variations from year to year are exaggerated.



Tube well amenities : Meerut.

Drinking water. Bathing tank. Washing tank.

useful service. But we are always brought back to the same fundamental trouble : the absence of an agricultural aristocracy or educated agricultural middle class recognising responsibility towards the community, and so long as that continues the villages must continue to suffer.

The Improvement of the village.

The absence of the educated middle class agriculturist is intimately bound up with the unattractiveness of the villages : the malnutrition and unhealthiness, and the inertia engendered thereby. As things stand few educated men or women will voluntarily live in the village if they can find posts in the town.

The improvement of the village should therefore be an integral part of the programme for the improvement of agriculture.

Thanks to the personal interest of the Viceroy, the movement for village uplift is spreading widely and is attracting large numbers of workers of different kinds. This is one of the most hopeful things in modern India and much experience has now been gained as to the different methods of procedure. I recommend that at an early date a conference of selected workers be called for the purpose of putting their experience on record for the guidance of others. It is extremely easy for village welfare work to degenerate into sloppy sentimentality from which the villagers gain nothing whatsoever. The only safe foundation on which to work is accurate knowledge of the facts and careful studies of the probable effects of proposed remedial measures. The only hope of permanence is to implant in the villagers the wish and the readiness to do the work themselves. So long as the improvements are done or paid for by someone outside the village community it is more than likely that they will cease altogether when the help is withdrawn. Model villages set up by benevolent patrons are rarely permanent unless the spirit of improvement has been deeply inculcated into the people, and then there is hope for the future. Villagers have considerable leisure in which to do something for the community and once the custom starts they can achieve a great deal. Mr. Darling recently instanced a district in the Punjab where in the last three years the people had spent a considerable sum of money in improving the water supply and the santitation. The progress already made shows what can be done, and it is very desirable that the work should be suitably organised ; always, however, preserving its essentially voluntary basis and retaining as far as possible the help of those generous and enthusiastic people who have done so much for it already.

The village school.

Now that interest in village life is spreading and schools are becoming more numerous it is essential that the education should from the outset be on sound lines. A purely literary method is not suitable : it tends to take boys off the land rather than to show them how they may lead a fuller life in the village. Reading about nature study or about the parts of a plant is of little use unless it be done in the field or the garden where the plant is before the pupil's eyes and

the things can be seen as well as read about. This is not the place for a discussion of methods of rural education, and indeed it must be admitted that they have been far less fully worked out than methods suitable for cities, but, as pointed out on page 65, it is widely agreed that a garden forms an indispensible part of a village school and that the gardens of the district should supply the material for the teaching of the scholars. Although this problem lies outside my terms of reference I cannot refrain from pointing out the desirability of enquiring into practicable methods for giving Indian village boys an education that will make them better men and better cultivators.(1) It would be a tragedy if the efforts now being made to educate the children should lead to the depopulation rather than the betterment of the village.

Bridging the gap between the Experiment Station and the Cultivator.

Reference has been made to the fact that the yields at the experiment stations and on the farms of European cultivators(2) are not infrequently 50 to 100 per cent. higher than those obtained by surrounding cultivators : and also to the circumstance that the new selections and varieties which represent the highest achievement of Indian agricultural science are used only to a very limited extent. The ryot continues largely unaffected by the enormous efforts made on his behalf.

Once an improvement starts to come into practice it has some chance of spreading : the difficulty is to ensure the beginning.

The present method consists in setting up local demonstration farms and in doing plot experiments on the cultivator's land. Successes in the demonstration farm tend to be discounted by the circumstance that Government Departments can do things which cultivators cannot : and the plot method is limited to trials of new varieties, new ploughs, etc.

Better results would I think be obtained if instead of plots of an entire holding were used for demonstration, supervised by a cultivator and not by a paid Government servant. The best cultivator could be selected and required to run his holding on a plan that comprised all the improvements which the experimental staff considered ripe for introduction : in return for this he could be furnished

(1) The Achimota methods might be studied.

(2) Colonel Bruce of Brucepur, Lyallpur, has favoured me with the following figures showing his yields as compared with those of his predecessor :—

	Maunds per acre.	
	Col. Bruce's yields.	*Previous yields.*
Wheat	8—24	11
Cotton American 4F	7·5	6
Other varieties	13·5	5
Gram	8·—24	11
Toria	not grown	6

free of charge or at a considerable rebate with the seed, and the loan of the implement to be demonstrated. A demonstration of this sort would have a vitality that is at present lacking.

I attach great importance to requiring the staffs of the experimental farms to make more of their experiments on cultivator's land. A weakness of some of the stations I visited was their somewhat closely self-centred life : much time and energy is devoted to the amassing of data the value of which it is difficult to see, and the work is confined to the Station. If some of this time and energy were devoted to experiments on outside farms the work would gain in value ; the experimenters would widen their experience and the cultivators would certainly learn something from them. Some payment would of course be necessary to compensate for disturbance of cultivation but the advantages would be considerable.

Much of the extension work, however, must be done orally and here of course agricultural officers differ greatly in efficiency. The really good extension officer, like the good research worker, is born, not made, and when one is found he should be kept at the work and should not need to seek promotion in some other direction. Dialogues, songs and other devices are all in use, and I shall long remember the crowd of villages gathered to hear the dialogue between the peasant who had failed to use his new plough correctly and the instructor who pointed out where he had gone wrong.

The possibilities of broadcasting deserve full investigation. Prices, addresses and dialogues can be widely disseminated in a variety of languages. All India Radio has already stations at Delhi, Calcutta, Bombay and Peshawar and proposes during this year to set up stations at various other places : Lahore, Lucknow, Dacca, Madras and Trichinopoly. Rapid progress is being made in the technique of broadcasting and it may become a most efficient agent in rural education. An integral part of a broadcasting scheme, however, is some means for giving prompt replies to enquiries : without this a great part of its value is lost.

CHAPTER 5.

The Machinery for dealing with these problems.

These problems are dealt with by the Agricultural Departments with the Imperial Council of Agricultural Research as the effective co-ordinating agency. The Council is organised on a wide basis with representatives of the contributing bodies and an expert administrative staff : it works through expert Committees composed of men having special knowledge of the problems concerned. I attended meetings both of the Committees and of the Council and was much impressed by the efficiency of the procedure which compares very favourably with anything I have seen elsewhere. During the short period of its existence the Council has accomplished a remarkable amount of good work and I do not see how its results could well be bettered.

In view of its success I suggest some widening of the scope of the Council.

The purpose of the research : the need for wider scope of the Council.

In pure science Research is an end *in itself*, and the workers' responsibilities end with the publication of his paper in one of the scientific journals. I agricultural research the case is different : it is not sufficient to point to the increasing girth of the Journal as the measure of success : the results must find some expression in the cultivators' or planters' fields or in the subsequent processing. It is much more difficult to make use of results than to get them, and in India the stage has been reached where the machinery for gaining more knowledge is working better than the machinery for utilising it. The Council should henceforward devote much of its attention to this problem of applying in practice the results already obtained.

At present the duty of applying the results devolves mainly on the Provinces, but some degree of centralisation is necessary, just as in the carrying out of research. The best method of dealing with this problem in my view would be to set up a Development Commission, whose function would be to work out systematic large scale plans for the improvement of agriculture and the raising of the standard of life in the villages, and to provide expert help and advice to the administrative Departments in carrying them through.

The Commission would deal with large groups of problems including—

(*a*) Soil Conservation deterioration and loss of soil exhaustion and manuring, soil erosion, salt, alkali.

(*b*) Crop Production, especially the planning of cropping schemes, the balance between cash, food, and fodder crops, the fusion of animal husbandry and agriculture.

the improvement of grazing land, the taking of action on the results of marketing and other economic enquiries.

(*c*) The exploitation of discoveries or processes of commercial importance. The Commission would not itself embark on industrial enterprises but it would smooth the way for others to do so by helping to bridge the gap between the laboratory and the factory, and by giving information and advice to the Commercial body undertaking the work. Seeing that some kind of monopoly would usually have to be granted for a term of years the Commission would advise the Government on the technical side as to terms that could be accepted.

(*d*) *The multiplication and distribution of seeds of approved* varieties of crops of named varieties of trees.

(*e*) The improvement of village roads.

The Development Commission and the Council would be so closely associated that it would be most economical both of time and of money to combine them in one body and to give to the present Council the wider powers needed for the developmental work. This would necessitate the appointment of another member of the higher staff to take charge of the Development side, but working in close touch with the present staff : and more assistant staff in order to liberate the higher staff for the necessary planning and thinking : in particular (1) an Editor, competent to take over the management of the Journal, Reports, etc., published from time to time by the Council, (2) an Expert trained in Geographical Science, (3) an Expert trained in agricultural economics both Experts to prepare critical reports for submission to the higher staff.

With this shifting of emphasis from gaining knowledge to applying it there would of course be a change in the Council's expenditure. It should be accepted as a general principle that the Provincial Departments should bear a substantial part of the experimental work done on their farms and from which they will derive benefit ; and the Council's funds thus liberated would be used for Developmental work. Further funds would, however, be needed, and the grant to the Council would require to be augmented : it is always costly to take the first steps in applying knowledge. In addition the possibility should be considered of setting up a Development Fund out of which grants or loans could be made for the carrying out of works proved by the experiments to be both feasible and advantageous.

The provision of staff.

However perfect the plan, the success of the work fostered by the Council is limited primarily by the quality of the men who are to carry it out. I cannot too strongly emphasise the fact that capacity for doing good research work is very rare : it is an inborn quality which cannot be imparted but can only be developed. On the other hand the training needed for an assistant can be given to

anyone, and a large number of people possess the necessary qualifications of honesty, industry, and scientific or technical knowledge. Unfortunate many Universities make no distinction between the two classes, and the distinctive label does not come till a man is so settled in his line of work that he is unlikely to make any useful change.

There is little difficulty in recruiting for Assistant posts, and a B.Sc. degree of one of the stricter Universities would usually guarantee suitable preliminary training. The Universities differ greatly in their standards, but this is well known to competent selection Committees.

Before appointing a University man to an agricultural post it is desirable that he should have a period of post-graduate training at the Imperial Research Institute at Delhi where he should be attached as assistant to one of the staff and required to read some of the classical books and memoirs on the subject. He could then take up his work and if after a few years he shows promise of development he should be encouraged to go abroad for two years study leave.

The difficulty of finding really good men for the higher posts is very considerable under any circumstances, even where the choice is absolutely free ; directly any limitation is set it becomes intensified. University degrees afford little guidance.

Selection Committee sometimes attach considerable importance to a Ph.D. degree. The value of this degree, however, depends largely on how and when it is taken. In itself it does not necessarily show a man to be a competent research worker or to have had a sound scientific training : it only means that he has worked in a laboratory where research is being done, and he was able under guidance to write a thesis conforming to certain standards. Here again, unfortunately, the standards are very variable, not only as between different Universities but also as between different subjects in the same University, and there is no way of discovering what the particular standard was. The D.Sc. degree of one of the stricter Universities is safer, but it is by no means an infallible sign of ability.

Testimonials also differ greatly in value. Much more useful information is obtained by asking the Professor under whom the candidate worked to furnish in confidence a report on his abilities as a research worker and his suitability for the post.

Numerous students from India go to Great Britain for post-graduate training. Usually they go too young. The change from an Indian to an English University Institution is so great that it should not be undertaken till a man has attained a certain maturity and experience of life and work, and till he knows what is likely to be most helpful to him in his subsequent career. With some notable exceptions the men who have gained most from post-graduate studies in Great Britain have, in my experience, been those who had previously held a post in one of the Indian Institutions, and who had done so well as to justify the privilege of study leave. They know exactly what kind of training they desire : they have sufficient experience and breadth of knowledge to be able to find their way

about the laboratory and the library, and they fit better into a research atmosphere and gain far more from it than if they come direct from completing their College course. They seek, of course, to obtain a Ph.D. degree, but they gain much more ; they learn something about the standards of work in a recognised good laboratory they meet and learn to know men of outstanding ability and distinction, while the serious attention they are able to claim enables the staff to form a shrewd opinion of their merits as investigators.

I recommend that the Council should set aside a small fund to assist senior men of proved merit to go overseas for training.

The Status and permanence of the Staff.

The Council's schemes are all temporary and in consequence the men actually doing the work are hampered by a feeling of insecurity and exposed to the temptation of making a good show of results in the hope of an extension of the grant.

It is impossible to avoid the element of temporariness, but its effects could be mitigated in three ways.

(1) A Provident Fund could be set up, which all members of the Staff would be compelled to join. The Cotton Committee have already a fund of this kind and their experience would no doubt afford valuable guidance to the Council.

(2) A Register of satisfactory and efficient research workers could be established, on which a man who had successfully completed the investigation assigned to him by the Council could have his name inscribed. This could be brought to the notice of Departments, organisations or private employers wanting good men.

(3) A selected cadre of proved research workers could be gradually formed, who would be given permanent posts and who could be transferred from place to place to carry out the investigations fostered by the Council.

I recommend that all three methods be adopted, and I am convinced that the moral effect on the men would be reflected in the work. No one can do his best when he is worried by fears of the future.

CHAPTER 6.

The Imperial Agricultural Research Institute, New Delhi.

The purpose of this Institution is to carry out investigations of fundamental importance to India agriculture in the same kind of way as is done at the Rothamsted Experimental Station or the Agricultural Research Departments at Washington. The difference in conditions is that Rothamsted is by far the oldest of the British Stations while the Delhi Station is the newest of those in India : and that the Washington Research Departments are under the control of the Federal Department of Agriculture of the United States while there is no such body in India. These differences give a special character to the Delhi Institute and they involve it in certain difficulties so that its position and functions need defining.

Among the Indian Agricultural Research Stations the Delhi Station occupies a special position, being controlled by the Government of India and placed under the general charge of the Honourable Member for Education, Health and Lands. The same Minister has charge of the Imperial Council for Agricultural Research so that the Council and the Institute may be regarded as parallel organisations, both responsible to the same Minister, but neither directly connected with the other.

The Research Institute is the direct continuation of the Pusa Institute, which almost from the outset was found to suffer from its isolated position, a difficulty that seems to have become intensified as time went on. After the destruction of the Pusa laboratories by earthquake in January 1934, it was decided to transfer the work to New Delhi and to build the new laboratories there. The difficulty of isolation is therefore completely overcome. Certain other weaknesses discussed in the various Reports on the reorganisation of Pusa have also been remedied, and the reorganisation of the Institute seems now to be satisfactorily accomplished. But meanwhile there have been some important changes in the position of agricultural science in India.

When Pusa was founded in 1904 it was the only centre for general agricultural research in India. Individuals such as Drs. Martin Leake, Barber, Hector and others were doing excellent work in their respective provinces, but their work was entirely personal and was in no way associated with an Institution. Pusa was intended as a centre where investigations fundamental to agriculture all over India could be carried out, and where agricultural officers might obtain trustworthy information on any important agricultural subject. In its early days the Institute was fortunate in attracting some exceptionally able scientific workers : the Howards, E. J. Butler, H. M. Lefroy and others, and in some respects it completely fulfilled the hopes of its founders : the wheats bred by the Howards, the masterly studies of the fungus pests by Butler and of the insect pests by Lefroy, are works of which any station could be proud. But these were all in the nature

of personal triumphs, and it is well-known that Pusa as an Institution did not attain the high commanding position in agricultural research that had been expected.

The new Research Institute begins under conditions very different from those in which the old Pusa started. There have been marked changes in at least three directions. The chief co-ordinating agency in agricultural research in India is undoubtedly the Imperial Council for Agricultural Research. It possesses the greatest of all powers in a modern state, the power of the purse ; it receives applications for assistance in reseach from all provinces and contributing states, it has fuller knowledge than any other body or individual of the problems of Indian agriculture and of the men who are achieving good work however quietly and unostentatiously it may be done. It combines therefore knowledge and power, and it is able to influence both the direction and the execution of research by the way it allocates its grants and the conditions it attaches to them. This powerful influence is likely to persist.

Further, agricultural research is no longer confined to one Station. The Provincial Departments have organised their own agricultural institutes, some members of which, with assistance from the Council, are making useful researches, and they feel no desire nor indeed have they any need to turn to a Central Institute for help or guidance. Several of the Universities have interested themselves in agricultural science and are carrying out fundamental investigations on plants and soils. Some of the other Departments and non-official organisations have their own research laboratories such as the well equipped Irrigation Research laboratory at Lahore, the Cotton Research laboratory at Matunga (Bombay), the cotton field station at Indore, the Tea Research Station at Tocklai and others. These have picked out for themselves some of the most important subjects and they are doing their work so well as to leave nothing over for a Central Institute.

Finally, the Imperial Agricultural Bureaux, and Institutes of Entomology and of Mycology, located at various institutions in Great Britain, and maintained by the various Governments of the Empire, including India, act as clearing houses of information on agricultural matters, identifying plants, insects, fungi, etc., and supplying information on the various branches of agriculture. These Bureaux have highly expert staffs and access to large libraries and herbaria : the need therefore for another clearing house of information at Delhi is much less than it was a few years ago.

In view of all these developments it might at first sight appear that there is little room for a Central Research Institute. If the Institute confined itself to the study of fundamantal problems basic to the work of the Departments without having secured the intellectual leadership, its results, even if sound, would run the risk of being ignored so that the work would have little practical effect. Intellectual leadership is won only by merit and only slowly : it cannot be achieved by administrative arrangements.

The Institute may yet win this leadership : it has magnificent buildings ; some prestige descends from the old Pusa ; and it is known that, in the selection of Staff, merit and competence are the chief determining factors, personal and communal considerations having no such commanding influence as in some of the Provincial appointments. All this is in its favour. It can best attain leadership by rendering valuable service to all concerned with the development of agriculture in India. But in the meantime the important question arises : how can the new Institute best aid in the development of Indian agriculture ?

The present work of the Institute.

The purpose of the present work is to provide a scientific basis for the activities of the various Provincial Departments of Agriculture. There is no intention of duplicating their work, or of carrying out investigations which they are able to make, but rather to undertake work of such wide application that it need only be done at one centre to serve all India ; and the fundamental studies for which they have neither the time nor the staff.

There are considerable difficulties in putting this design into practice. The fundamental studies cannot as a rule be separated from the practical problems to which they relate : usually the work must be done in the district concerned. Studies detachable from the field-work become indistinguishable from plant physiology, physical chemistry, genetics and other sciences more properly investigated at the Universities because of their intimate relation with teaching. It is of course possible to spend many life times on the study of any natural object and still not to exhaust the possible programmes of investigation : but the work soon becomes remote from practical agriculture and therefore unsuitable for an agricultural experiment station unless constant care is taken to keep it in the field as well as in the laboratory.

The detailed work of the Station is discussed in a later section of this Report. The various activities of the Institute fall into three groups :

(I) standardisation of methods for other stations to use :

(II) making collections of insects, fungi, soils, etc., and also a register of varieties of crops : all these to be available to the Staffs of Provincial Departments :

(III) investigations of agricultural scientific problems which seem to be near to practical application.

In regard to standard methods, the Institute has no power of compelling other stations to adopt those that it recommends, it can only point out their advantages.

The making of collections is very useful is assisting Departmental officers to identify any insect or fungus new to them. In case of uncertainty the last word will always remain with the

Imperial Institutes of Mycology and Entomology in London, where the staff have access to the type collections and to collections of living cultures, and which also act as clearing houses of information for the whole Empire. It would be very costly and quite unnecessary to attempt to duplicate their functions, and the Air Mail service is now so efficient that there would be no saving of time even if the attempt were made. Some of the provincial officers with whom I spoke preferred to apply direct to the Bureaux for identification and information rather than send to Delhi.

The future position and work of the Central Research Institute.

In view of these various considerations it seems clear that the most useful place for the Institute in the schemes for developing Indian agriculture would be in close association with the Imperial Council of Agricultural Research, recognising frankly the leading position which the Council has secured. The Council could undertake either the entire charge of the Institute or the supervision of its programme of work : this is a point of administration as to which I express no choice. But the Council should be empowered to require that the Institute's research programme included specified problems which it deemed important for Indian agriculture, even if this necessitated the cutting out of items which the staff would like to have included but which in view of the Council were of insufficient practical significance. The Council can, for example, and in my opinion should, insist that certain recognised methods of sampling and analysis shall be used for all investigations aided by it—without of course excluding any other methods which the workers may prefer—and that field experiments of all kinds shall be carried out in such a way that the results can be subjected to statistical examination with a view to estimating their validiy.

This necessitates, however, thorough examination of the methods before they are made obligatory for grant-aided researches and this work could be done better at the Central Institute than anywhere else.

Among problems which in my view should be taken up by the Institute at the earliest opportunity are the following :—

(1) Methods of sampling of soils(1) and of all of the important crops for analysis.

In general it will be necessary to work out two groups of methods, one for rapid approximate analysis, and the other for more refined investigations where some scientific principle is involved. The work must be done in association with the statisti-

(1) The difficulty of sampling a soil is rarely realised. Usually a sample is described as having been taken to a depth of 6 or 9 inches but this ignores the fact that a 6 inch core taken on a day when the soil is compact is very different from a 6 inch core taken when the soil is in loose or swollen condition. Serious discrepancies may thus be caused in estimating the quantities of substances like nitrogen and nitrate, the content of which varies with the depth.

cal experts, who must be able to accept the methods as giving valid estimates of significance of the results in view of the heterogeneity of the material.

(2) Standard methods of analysis and of crop examination to be used for all co-ordinated schemes. Individual workers would, of course, still be at liberty to use their own methods, but the standard methods must also be used to ensure comparability of the results.

Both (1) and (2) would necessitate considerable laboratory and field investigation : it would not be permissible simply to write down arbitrary methods and insist on their use. Numbers of alternative methods would need to be examined experimentally, and the Institute must be able to set out and justify before expert critics the reasons for its selection. International methods should as far as possible be adopted unless others are definitely better.

(3) Collection and examination of soil analyses made in different parts of India with a view to the preparation of soil maps. Until the standard methods referred to in the preceding paragraph are universally adopted it may be necessary to analyse again some of the soils, and numerous examinations would be needed in order to find how far soils examined by different workers are similar and how far they differ. This would necessitate the setting up of a small soil Committee consisting entirely of the leading soil experts of India to act as the correlating body : the Chairman of the Committee would not necessarily be a member of the Institute staff. A considerable amount of valuable material now exists in various parts of India ; following up the recommendations of the Royal Commission on Agriculture a number of surveys have been made both by Agricultural and by Irrigation Departments. All the data should be collected and collated.

(4) Comparisons in field experiments of the relative values of nitrogen in green manure, farmyard manure, compost, oil cakes and sulphate of ammonia. Estimations of the recovery of nitrogen by the crop, and of the changes in moisture, ammonia and nitrate contents of the soils of the different plots. The work must be done in the field, the treatments being properly replicated and the plots randomized in the usual way, and the sampling to be so done as to give on each occasion a valid estimate of the error of the sampling.

(5) Collection of insect and fungus pests, and of other insects and fungi associated with crops even if of no present economic importance. The collection and compilation of records of occurrence at periodic intervals at a number of centres where it is known that the observations are trustworthy. To this should be added information obtained from the Imperial Institutes of Mycology and Entomology at London and the whole should periodically be put into the form of short bulletins which busy

Provincial officers could read, and which would inform them of any apparent increase or decrease in the pest, and of results of attempts to obviate or to overcome the attack.

(6) Population studies of insects as discussed above. The methods of sampling and estimating must be worked out experimentally in association with the statistical experts : methods of recording should be devised suited for use at all the stations. The results should then be collected and fully worked up at the Imperial Station.

The Tea Research Station at Tocklai should be consulted as to methods of recording the incidence of insect and fungus attack.

(7) Collection or registration of varieties of crops, fruits and vegetables grown in India.

It is unnecessary to duplicate existing collections of importance, but the varieties should be included in the records.

(8) Selection and breeding of plants for which there is no adequate provision in the Provinces, *e.g.*, potatoes, or for which Delhi or its substations are particularly well suited, *e.g.*, the Brassicae at Karnal. Co-operation with plant pathologists in plant breeding experiments, *e.g.*, for producing rust resistant wheats.

(9) Continuation of the selection and breeding of sugar cane at Coimbatore on its present lines.

(10) Co-operation with the Health Department in investigations likely to improve the quality of the dietary of the villagers : *e.g.*, practicable methods of making good the deficiencies of the customary diets : the effects of proved mineral deficiencies in soils on the nutritive value of cultivated food stuffs.

(11) Co-operation with the Marketing branch in making or arranging for investigations likely to improve the market value of Indian agricultural products. This work should be confined, however, to investigations likely to come to a successful issue : vague investigations in " quality " should either be avoided, or done on a large scale as described on page 23.

(12) Keeping in touch with the workers engaged on the Council's schemes, lending them books and current journals (so far as these would be replaceable if lost) containing papers of importance to them.

Irrigation and dry farming methods are of such vital importance and present so many difficult problems requiring investigation in the regions concerned, that I recommend separate treatment for them (page 220). The Institute would continue as at present to admit post graduate workers but it should be empowered to insist on a high standard of attainment before entry. There are

numerous facilities in India for ordinary tuition in agricultural science, and it would be unfair to the Staff and a waste of their resources, if they had to teach facts and methods that are included in a good College course.

The above programme differs in several respects from the tentative proposals put before me when I visited the Institute.

I have omitted all subjects not directly applicable to the production of crops under present circumstances : such as pure cytology, microbiology and physiological studies of insets and fungi. I recognise their interest, and should welcome their inclusion, especially if members of the Staff are personally interested in them, provided they can be studied without prejudice to the work on the items set out above. But, I consider the need for improving the yield and quality of the cultivators' produce is so urgent that all other problems should stand aside. In the present day conditions in India the Experimental Stations both Central and Departmental must be judged by the extent to which they help to raise the standard of life in the villages.

The Staff of the Institute : The Director.

The position of the Institute in relation to the Universities and the Departments of Agriculture depends on the quality of the work done there, and this in the end depends on the quality of the Staff. The Director and the Heads of the leading sections should if possible be men of international repute who would be respected for their own merits by the workers at other Institutions. This, of course, is easier to lay down as a principle than to accomplish as a fact.

It has been proposed that the Director should also be Head of a Department but this arrangement while no doubt suitable as a temporary measure during a period of financial depression, is not in my view suitable as a permanency. There is always the danger that heads of other sections may consider that their claims to share the available funds are being set aside in order that the Director may better finance his own section. Further, the directorial duties cannot fail to interfere with the duties of head of section and to take up time that would normally be devoted to research. Additional work devolves on the chief assistant, and although this may to some extent be met by additional payment, the fact remains that he is charged with the responsibility of special supervision without the prestige which for the scientific man is often more important than the extra pay.

Finally, the Director should be one of the most useful of the group of thinkers and planners helping the Council in its new developmental duties. He should be a scientist of wide repute and having such personal qualities that his help and criticism would

be welcomed by the men carrying out the Council's research schemes. He need not be an agriculturist but he must be distinguished in some science basic to agriculture. It is not necessary to go outside of India to find a suitable man.

The present Staff of Research Workers engaged on the Council's Schemes.

I greatly admired the energy and enthusiasm with which many of the research workers engaged on the Council's schemes were carrying out the tasks allotted to them, in spite of great difficulties. It is of course pleasant enough to do research at a University where there is an intellectual atmosphere and a social life rich in amenities, where libraries and the other accessories of learning are available. But many of the Council's workers are in lonely places where they are cut off from any possibility of discussing their results with competent critics, away from libraries and the stimulus that comes of association with men distinguished in the arts and sciences. And yet in spite of these difficulties and of occasional depression through a feeling of isolation they are achieving good results. Many of the difficulties are unavoidable : they arise from the circumstance that the work must be done on the spot and cannot be transferred to a College. They could, however, be considerably mitigated by more frequent visits from experts who could go over the results in detail and discuss them with the worker. The interest taken in the periodic visits of the Council's experts shows how valuable these discussions are, and the Council might well consider the advisability of extending them by periodically sending some other qualified person to Stations where his special knowledge would be helpful. Visiting Experts should pay particular attention to the more remote and inaccessible stations, and should stay at each place long enough to go into the details of the results, advising what lines should be followed up and what can be left for the time being. It is difficult to over-rate the value to a research worker of a quiet talk in his laboratory or on his field plots with some one enjoying sufficient prestige to command his respect, who is taking the trouble to understand his results, and who can deal helpfully and sympathetically with his difficulties. Such visits would necessarily be infrequent, yet their influence would, I am sure, be profound, and a young man proud of his work would be greatly encouraged by the knowledge that his visitor had recognised its good points, and had indicated ways in which improvements might be effected.

Still further benefit would accure if arrangements could be made on the recommendation of the visiting expert for the worker to spend a certain period of time in some other laboratory where similar investigations were in progress or where methods likely to help him were being developed. A detailed programme would be drawn up in consultation with the Heads of the laboratories

concerned, and submitted to the Council, who, if they approved, would take the matter up with the Departments.

Technical Conferences between the workers in similar subjects are already arranged : I should like to emphasise their value. The Council might consider the advisability of holding some of these conferences at the Imperial Research Institute, Delhi, in the laboratories where methods or technique could be demonstrated instead of being simply discussed.

Proposed permanent cadre of proved research workers.

Some of the men now engaged on the Council's schemes have shown definite capacity for doing good work and it would be a great loss if they were simply released at the end of the period. It is undesirable and indeed impossible to retain all, but a select group should be put on a permanent basis, working usually at some out-station where they get down to the actual field problems, but regarding the Central Institute as their home. The posts would be permanent, but a man would not necessarily remain in this cadre indefinitely, for from it would be recruited men for administrative or executive posts requiring technical knowledge. A man's research life is not usually very long : in general—and with some notable exceptions—however good he may be, he sooner or later gets into a groove out of which he will never again emerge. It is no misfortune when a research man who has the gift for administrative work undertakes it after having opened up a new field of enquiry.

The organisation of the Council's business.

I attended meetings of the Council and of various sub-committees and was much impressed by the evident effectiveness of the procedure. At first sight the Council seemed large but I could suggest no way of reducing their numbers.

In view of the widening of the scope of the Council's activities which I have proposed it will obviously be impossible for the Council to concern itself with individual schemes : it should deal with principles and major issues rather than details, and while it would place the large problems in some perspective it would necessarily leave to the higher staff and the sub-committees the detailed shaping of schemes and allocation of funds thereto.

The method adopted by the Council of appointing sub-committees of experts to discuss and report on the various divisions of their work is admirable and suitable for extension.

The expenditure of the Provincial Departments.

Reference has several times been made to the successful work of some of the Provincial Departments. The figures of provincial

budget estimates for 1936-37 on account of the Departments of Agriculture in the various provinces are shown in Table 16.

TABLE 16.

Province.	Total area sown. Million acres.	Expenditure on Agricultural Department.	Expenditure per 100 acres sown. (total sowing).	Expenditure per 100 persons.
		Lakhs of Rs.	Rs.	Rs.
N. W. F. P. ..	2·5	4·77	19·1	..
Assam	6·7	8·12	12·1	9·4
Madras	37·5	41·75	11·1	8·9
Burma	19·1	18·09	9·5	..
Punjab	29·8	28·52	9·6	12·1
Bengal	27·9	25·65	9·2	5·2
U. P.	43·4	36·70	8·5	7·9
Bihar	..	13·20	..	..
Bombay	34·1	22·46	6·6	10·9
C. P.	27·5	9·42	3·4	6·1

The Council's Resources.

The Council's work has been financed on generous lines by the Government of India and it has received substantial grants from other sources. The effect of the foregoing proposals will be to diminish the expenditure in some directions and increase it in others, but if a total income of the order hitherto received should continue to be available much of what I have proposed could be carried out. During the next few years, however, the Council would need additional special grants if progress is to be as rapid as is desired.

PART II.

PART II.

Work directly carried out by the Council.

In general the Council does not itself undertake investigation. There are, however, two directions in which it has done so : costs of production of crops, especially cotton and sugar cane ; and the statistical control of agricultural experiments.

(1) Cost of production of crops.

This investigation is in the hands of Mr. R. D. Kapoor, who after graduating at Lyallpur travelled with the purpose of studying economics at Columbia and New York ; agriculture at Cornell ; and agricultural economics at Cambridge under Dr. Venn. The cost is estimated at Rs. 5,25,800 of which only half is borne by the Council, the other half coming from the Indian Central Cotton Committee.

The general plan is to select 24 districts all over India where sugar cane or cotton is an important crop ;(1) to choose six villages in each district and eight holdings in each village. A Recorder is placed in each of the villages to keep close watch on the selected holdings, entering up all the work done, by whom it was done, and the number of hours taken. A District Supervisor is in charge of each six recorders, and is required to spend at least 20 days per month in the villages. A provincial officer checks the work of the supervisors.

There are thus 1152 holdings under observation, and the staff includes 144 recorders, 24 district supervisors, in addition to the central staff.

The common difficulty of assessing the value of a peasant's time was met by enquiring into the local wage rates and charging the hours at these rates. The rates vary considerably in the different districts ; for a man working 8-10 hours a day the wage in Sind is 6-8 annas : in the Punjab 3-4 annas : in Madras 1 anna 6 pies to 2 annas. As the enquiry proceeds it will be interesting to see whether the rates per unit of crop produced vary as much as the rates per day, or whether, as often happens elsewhere, the rates even out, the cheaper labour being less effective than the dearer.

This is the first enquiry of its kind in India, and the results if valid should be of value both to the Agricultural Departments and in relation to the work on Rural development and village improvement. The work should certainly be continued, but a close study of the data should be made quite independently so as to ascertain whether they have been correctly used.

A first inspection of the figures suggests that cotton is profitable in the Canal Districts of the Punjab and in parts of Bombay and Madras : sugar cane is profitable in the United Provinces, in Bihar and parts of Madras, while in the Punjab it only just pays :

(1) The districts were scattered widely : there were 3 in the Punjab, 3 in the United Provinces, 3 in Madras, 4 in Bombay, 3 in the Central Provinces, 3 in Bihar and Orissa, 2 in Bengal, and one each in Sind, Hyderabad State, Baroda State, and Mysore State.

wheat is profitable in the canal colonies of the United Provinces and the Punjab but not elsewhere. " Unprofitable ", however, does not mean, as it would in Great Britain, that the grower had lost money, but only that he would have been better off had he spent the same time as a labourer at the standard wage assuming he had been able to obtain the work. It will be interesting to ascertain also whether the peasant has himself discovered the relative profitableness of the various crops and extended his acreages accordingly.

It is understood that this scheme comes to an end when the present enquiry is completed.

(2) Statistical control of agricultural experiments.

Rao Bahadur M. Vaidyanathan, the Statistician to the Council received his mathematical training at the Madras University where he specialised in Statistics. His duties consist in assisting investigators in designing their experiments, both in crop and animal husbandry, and in examining the results ; in reporting on articles submitted for publication in the Council's Journal, and in advising the Council on statistical matters generally. At the time of my interview he was closely watching some 56 schemes in various parts of India : in addition he is studying methods of sampling and methods of crop forecasting ; and he is aiming at preparing Statistical Tables for field workers. He has also prepared and published a summary of all the recorded manurial experiments made in India.

All these subjects are of great importance. It is impossible to over-estimate the need for statistical control of agricultural experiments, particularly in ensuring sound design of experiment and effective methods of sampling. It is significant that in his review of the fertilizer investigations the Statistician had to reject a large number of the experiments because of faulty design.

This trouble is not likely to recur, as the improved methods worked out at Rothamsted have been eagerly taken up by Indian investigators, and in any case the Council now insist that all designs of crop and animal husbandry experiments must be approved by their Statistical adviser before any grant can be made. In some instances the experiments had actually been begun before the Statistician was consulted, and all he could do then was to save what he could of the results. At the risk of apparent loss of time this should not be permitted : a faultily designed experiment can never give satisfactory results no matter how often it is repeated or how carefully the work is done.

An instance came to my notice where another statistician had also been consulted and he had suggested a different design for the experiment, which caused some comment at the time. There is nothing unusual in this, and no harm at all in having alternative design for consideration, but as an act of courtesy each Statistician should know that a second opinion is being asked, and from whom. The final decision rests with the Council, but in case of serious discrepancy the two statisticians should be invited to give detailed reasons for their choice.

In view of the circumstances that the subject is new and outside the range of training and experience of many of the workers, it is very desirable that Rao Bahadur Vaidyanathan or some highly competent officer should periodically visit the various stations where research under the aegis of the Council is done, in order to ensure that the experimental schemes as they develop can still bear statistical examination and that the significance of the results can be estimated. It is particularly important for experimenters to realise that no amount of statistical treatment can ever make a bad experiment into a good one. Statistical science can sometimes mitigate the loss of value due to some accident, as when it shows how to extract a result in spite of the loss of crop from one of the plots, but the need for salvage operations of this kind should be sedulously avoided.

Much work needs to be done on methods of sampling. Agricultural materials, soils, crops and animals, are very variable : no two are alike : and it is impossible to say how much of the difference between a treated and an untreated sample is due to the treatment and how much to the heterogeneity of the material. Sampling therefore becomes an operation of fundamental importance, and a considerable amount of experimental work done in the past, and some that is still proceeding, to which I refer elsewhere, is seriously vitiated by faulty sampling. The method must be suited to the material and adequate for the problem : but considerable investigation needs to be done in order to work out model methods for the various types of investigation now proceeding.

Another subject needing serious attention is the improvement of the agricultural Statistics. The figures for acreage are, or can be made, fairly accurate, but the estimates of yield are very uncertain and some experienced agricultural officers have gone so far as to assure me that they are worth very little. When checks became possible for yields of cotton the values recorded in the agricultural Statistics were found to be about 25.30 per cent. too low. In view of the great interest now being taken in the nutrition of the villagers it is important to know whether the recorded yields of food crops are subject to a similar error.

This problem is really only another example of sampling. Other sampling problems concerned with rural welfare are discussed on page 157. The subject is rapidly developing and I note with satisfaction that Rao Bahadur Vaidyanathan is to proceed to England for one year to familiarise himself with the latest developments and to discuss Indian problems with various experts there.

The present staff consists of Rao Bahadur Vaidyanathan and two assistants only and in my view it needs strengthening. More computers and compilers are required : they can be obtained without great expense. But the senior staff will need to be increased in the near future. Further reference to this matter is made in discussing the work of Professor Mahalanobis in Calcutta.

Statistical work of this kind is necessarily continuous, and I recommend that the section be made permanent.

IMPERIAL INSTITUTE OF AGRICULTURAL RESEARCH.

(See page 74.)

ACTING DIRECTOR : RAO BAHADUR B. VISWANATH.

The Institute is organised in five sections :

(1) *Agricultural Section.*—In charge of Mr. Wynne Sayer. Good work has been done in building up a high class pedigree herd of Sahiwal cattle, on which Dr. Wright is reporting. Mr. Sayer also proposes to study power farming.

The main farm area comprises one compact block of 475 acres and a further area of 50 acres. In addition land is available at Karnal, 70 miles to the north of Delhi, and easily accessible by rail or road.

(2) *Chemical Section.*—This is in charge of Rao Bahadur B. Viswanath. A soil survey of the farm is being made with the view of relating the cropping capacity of the soil to the crop yield. If this investigation can be adequately carried out it may yield results of considerable interest, but it implies the collection of a considerable quantity of yield data of known validity.

The possibility of making a compost from forest litter is being studied.

The effect of farmyard manure on the quality of the seed is studied : it has been claimed that seed from plants receiving farmyard manure produces better plants than from unmanured plants.

It is known that large plump seed gives larger and more vigorous plants than small shrivelled seed, one factor being the difference in food supply for the embryo and the plantlet. In this investigation it will be necessary to separate the effect of size of seed from any specific effect that farmyard manure may be exerting.

The nitrogen content of the soil is studied with the special purpose of finding whether it remains approximately constant during the year or whether it is liable to seasonal fluctuation. This question is of considerable scientific interest though it probably has no practical significance. The investigation has been carried out at a number of centres and a number of analyses have been made.

The actual figures obtained at the different times of sampling all differ, being sometimes above and sometimes below an average value ; the differences are only small but they are greater than any likely error of titration. It is assumed that these fluctuations represent real changes in nitrogen content of the soil, but this assumption is not justified : no two samples of soil from the same plot of land contain quite the same percentage of nitrogen and unfortunately the results do not show how much of the recorded fluctuation is due to differences in the soil itself. The method of sampling is faulty in that it gives no measure of the soil heterogeneity and in consequence nothing can be deduced with certainty from the results. A better sampling technique is needed.(1)

---

(1) Several possible errors are discussed in a paper by A. Sreenivasan and V. Subrahmanyan, " Some Factors Influencing Studies on Nitrogen Fluctuations on Soil Plots ", Proc. National Inst., Sci., India, Vol. III, No. 2, pp. 233—239.

On the applied side work is being done on gur and on the clarification of sugar.

A laboratory has been set up for the special study of micro-chemical analyses. The purpose is to develop methods which can be used by various departments here and in the Provinces.

The Micro-biological laboratory is in charge of Dr. Joshi. He is at present studying the supposed photo-nitrification stated by Dr. Dhar to occur in soil. (See page 118.)

Further, he is studying the dissociation of bacteria supposed to be associated with mosaic disease. Some of the dissociated forms are filter passers : a matter of some theoretical interest. Other problems include the bacterial control of milk and the bacterial oxidation of sulphur, an action that would presumably occur if composts were made of sulphur and bones for the purpose of preparing superphosphate.

(3) *Botanical Section.*—At the time of my visit Dr. B. P. Pal was Acting Imperial Botanist. He is investigating problems of plant breeding and genetics. Some of the work, such as the breeding of potatoes resistant to blight, is done in the fields at Pusa.

He proposes to set up a register of the different varieties of wheat in cultivation in India and to give them standard names. This work appears to be well done.

(4) *Mycology Section.*—Mr. Galloway was still in charge at the time of my visit but he has now left and Dr. M. Mitra is Acting Head. The general programme comprised two parts :

(I) The maintenance of a collection of the chief fungi of importance in India : this is in two parts : the herbarium specimens and the living specimens, though it was recognised that this latter would be difficult and costly to maintain because of the continual sub-culturing necessary.

(II) Practical control of fungus diseases : this work, however, is not to overlap with work in the Provincial Departments.

With the appointment of a new Head of the Section it would be well to reconsider the scope of work and the name of the Section. "Plant Pathology" would in my view be a better name than "Mycology" and would better express the scope of the Section. Since the original section was set up it is now recognised that plant diseases are caused by a variety of agents, not only by insects and fungi : there are also bacterial, virus and physiological diseases. All these should come within the scope of the Section. It is no longer necessary that the head of the Department should be a mycologist : he should be a plant pathologist, and if necessary should have a mycological assistant.

(5) *Entomology Section.*—Dr. Pruthi is in charge of this Section with Mr. P. V. Isaac as second entomologist. He has three main lines of work :

(I) A collection of insects associated with Indian crops and fruits whether of present economic interest or not, it being recognised that an insect harmless now may be harmful

in a few years time. A record of the occurrence of these insects with notes is also kept.

(II) Studies of the life-histories of Indian insects. The provincial entomologists study only recognised pests.

Sheets are prepared showing the occurrence and damage done by the pests, and methods of control are discussed.

In view of the fact that some of the Provinces have no entomologist(1) this work is likely to be very useful.

(III) Studies of vegetable insecticides and fish poisons. (See page 196.)

It is proposed also to study bees.

In addition the Agricultural Section is provided with a statistical assistant, Mr. P. V. Krishna Iyyer, for carrying out its routine work.

The Schemes of the Imperial Council of Agricultural Research.

Three of the Council's schemes are being carried out at the Institute : they are all connected with sugar cane.

(1) Mosaic and other diseases of sugar cane ;

(2) Insect pests of sugar cane ;

(3) Chemistry of sugar cane.

(1) MOSAIC AND OTHER DISEASES OF SUGAR CANE:

This work was begun in 1932, at first under Dr. S. Desai, but now in charge of Dr. B. L. Chona ; and the amount of the grant is Rs. 18,596 annually for 5 years and Rs. 12,000 non-recurring : the total being Rs. 1,04,980.

(*i*) *Mosaic disease.*—A good deal of attention was at first paid to Mosaic disease but this is not now regarded as serious at any rate in Northern India. Even an 80 per cent. infestation caused only a 10-15 per cent. reduction in yield, and under normal conditions in practice, the infestation rarely exceeds 10 per cent., and sometimes is only 1 or 2 per cent.

The observations have hitherto been mainly on the medium Coimbatore varieties ; they are now being extended to the thicker varieties, but there is at present no indication that the results will be different.

It is never safe, however, to assume that Mosaic diseases are unimportant. They form an obscure and difficult group and they have the peculiarity that two known diseases can combine to form a third, new to plant pathology and capable of causing considerable trouble. Further, new varieties of cane may be produced which, while desirable in other ways, are susceptible to Mosaic disease. Constant watch must therefore be kept : but this is not a matter for the Council ; the Imperial Agricultural Research Institute is a suitable body for this purpose.

---

(1) *E.g.*, Bengal, Bihar, Sind.

In view of the relative unimportance of mosaic disease of sugar cane there seems no particular need for continuing the work on the properties of the virus. Studies on this subject are being made elsewhere but until some striking fresh development occurs it is hardly necessary to repeat on sugar cane work already done on potato or tomato virus.

The work is in any case more appropriate for a University well equipped for plant pathology, and having available good chemical and medical laboratories so that the help of experts in other subjects can be obtained whenever necessary. It is essentially a problem for a team and not for an individual.

For those crops for which it is serious the best way of dealing with the disease is to grow resistant varieties, and this would probably hold for sugar cane also if ever the disease gave trouble in India. Meanwhile it is necessary to test all new varieties for resistance to mosaic disease : a suitable technique has been worked out by Dr. McRae and Rao Bahadur Venkataraman.

(*ii*) *Red Rot*.—This disease is much more important especially on the thick varieties : indeed it is probably the most serious sugar cane disease in India. The remedy consists in a more careful selection of the sets, all those showing redness on cutting being rejected. There is a reddening caused by saprophytic organisms, following the attack of the borer, and in consequence the rejections of all red sets may involve some loss, but it is safer to incur no risk. Two other rots are studied.

(*iii*) *Stinking Rot*.—(*Bacillus pyocyaneus* var. *saccharum*, *Desai*) apparently a bacterial disease though its cause is not yet known, and *Top Rot*, which is apparently caused by Fusarium.

In addition to these studies of disease two other pieces of work have been undertaken :

(1) a survey of the diseases of sugar cane in the important cane growing regions of India ;

(2) a handbook of the diseases of the sugar cane, describing them and showing how they should be treated.

It is very desirable that these should both be completed.

Insect pests of sugar cane.

Entomologist in charge : P. V. Isaac.

This investigation began only in 1936 : a grant of Rs. 96,000 has been sanctioned.

The programme of work includes four sections :

(1) Field work on insect pests at Delhi, and at the sub stations of Karnal, Pusa and Coimbatore.

(2) The collection of parasites on borers, Pyrilla, and White fly with a view to investigating the possibility of biological control.

(3) The investigation of indigenous parasites, and the importation and trial of exotic parasites

(4) **Bionomic work on pests, and the collation of information.**

So far the work has been confined to sugar cane borers :

Steam borers—*Argyria sticticraspis* and *tumidicostalis Diatraea venosata* and *auricilia* and *Chilo zonellus*;

Top borers—*Scirpophaga nivella and monoatigma* ; and

Root borer—*Emmalocera depressella.*

These same insects are also studied at Muzaffarnagar, at the Punjab stations, and elsewhere. The Delhi Institute can properly carry out investigations at Karnal, but Coimbatore is far away and already a provincial entomological staff is at work there. If all these entomological investigations are carried out independently there is likely to be considerable overlapping and waste of effort, but under a central staff the necessary co-ordination could readily be effected.

Possible biological control of insect pests.

In the Central Scheme of Research on Insect Pests of Sugar Cane it is proposed that considerable attention be paid to the possibility of biological control. This is at first sight an extremely attractive method of dealing with insect pests ; hitherto its successes have been mainly in dealing with introduced pests or in islands or areas naturally isolated by mountains or deserts. It is discussed on page 50.

The investigation of the pests in the field : population studies.

At the present stage it is very important to make a fuller study of the insect and fungus pests in the field, noting their first appearance on the crop ; whether they die out, just persist, or continue to increase ; noting also the changes in external conditions : temperature, moisture supply, condition of the plant, percentage of sugar and brix (as read by the small instrument now available for use in the field) : with the view of discovering the conditions that vary with, and perhaps make for, the spread or suppression of the pest. While the observational work is going on there should be attempts to obtain and to count " samples " of the insect population so as to gain a more definite idea as to how the numbers are changing.

In conditions such as those obtaining in the sugar cane areas all the common insect and fungus pests of the crop are almost certain to occur every year in some or other of the fields, but the conditions are not necessarily always suited to their development. With a fuller knowledge of the conditions under which the pests increase, and of those under which they decrease, it should be possible to make changes in the cultivation of the sugar cane that in normal seasons would carry it through without important loss.

The search for resistant varieties of sugar cane must of course continue. This is not a permanent method of control, for after a while the insect pest usually adapts itself to the new variety, but for a time it affords a measure of protection and meanwhile selections of other varieties can be proceeding. The insect pest problem is

much more difficult than that presented by fungus pests. Considerable success has been attained in seeking for varieties of crops resistant to fungi, but so far the success obtained against insect pests have as a rule been only temporary.

The machinery for dealing with the pests and diseases of sugar cane.

The simplest method of dealing with the pests and diseases of any crop is to put a staff of entomologists and plant pathologists in charge of the work and to free them from other duties. Specialisation is essential if the crop is really important. The setting up of a Sugar Committee provided with funds for investigating the problems of sugar cane production makes it possible to establish a central specialist group of workers for dealing with pests and diseases and to provide also the local staffs who can make the necessary continuing observations and experiments : I strongly recommend that this be done as soon as possible.

The central staff would be housed at the Delhi Institute where the records would be worked up, but wherever a disease or pest was threatening to do serious injury they would transfer to the Station concerned.

The assistance of the factories could also be secured in making surveys similar to a valuable one recently completed by Dr. Haldane of the Begg Sutherland group of factories.

Cytology.

GRANT : Rs. 29,360, to be spread over 5 years.

A scheme has been put forward and is still under discussion for investigations into the cytology of Indian crops.

Cytological studies give valuable information to the plant breeder about the genetics of crops, and at the larger experimental stations where much hybridisation is done it is desirable that someone, preferably the plant breeder himself, should have learned the technique of making cytological examinations and extracting the information they can yield. This work must be done at the Stations where the crops are bred and studied : it cannot be carried out anywhere else.

The question of supporting cytological investigations at a University is on a different footing. These might result in new knowledge of the principles of cytology, and, of course, they would stimulate the training of men and women in the subject, and so would indirectly benefit agriculture.

Karnal.

Sub-Station of the Imperial Research Institute. Botanical Station of the Imperial Council of Agricultural Research.

(Visited November 12th, 1936.)

Like several other experimental farms I visited, this farm was not started as an agricultural station but by some other public

authorities, who, finding it unnecessary or unsuitable for their needs, passed it on to the Agricultural Department. In this case the founders were the military authorities. The farm has till recently been divided into two parts :

(1) a Botanical station of the Imperial Council of Agricultural Research for experiments on cane sugar and wheat ;

(2) an extension of the farm at the New Delhi Research Institute to give the agriculturist more land for experiment and to provide further accommodation for the cattle. The distance from New Delhi is 70 miles but it can be traversed by motor-car in about 2 hours as the road is very good. Karnal is in the Punjab, but almost on the border of the United Provinces

In this report I deal only with the first of these sections.

Sugar cane Substation: Sugar cane investigations.

These were started in 1931 and are in charge of Messrs. R. B. Venkataraman and G. V. James with a Technical Assistant. The annual cost is Rs. 12,500 with a non-recurring grant of Rs. 32,000 : the sanction is for 8 years making a total of Rs. 1,32,000.

These experiments form part of a joint scheme of work carried out on uniform lines at several centres in Northern India. Three major problems are investigated :

1. Varieties are sought which are better suited to the local conditions than those in actual cultivation.

2. Cultivation and manurial experiments are made with the selected varieties to discover means of economically increasing their yields.

3. Attempts are made to lengthen the working season for the factories by increasing the yields of early varieties and the keeping qualities of late varieties, thus making their cultivation more attractive to the cultivator. A special advantage of the early varieties is that they enable the cultivator to catch the early market for gur.

At Karnal the Coimbatore seedlings only are tested : no crossing is done as only a limited number of varieties flower here. No difficulty is experienced in bringing the seedlings from Coimbatore. The journey takes about 72 hours but arrangements are made for the seedlings to be watered and tended *en route.* Over 1,700 have already been tested. It has now, however, been found possible to germinate seed at Karnal ; " fluff " is brought from Coimbatore and the canes raised : all stages of the selection can therefore now be done here.

The seedling canes are grown first in short rows where all are rejected that possess such objectionable characters as a sprawling habit of growth, or liability to certain diseases ; the survivors are then grown in plots and subjected to further selection. This method is adopted at all centres.

The canes are planted in March, somewhat later than in many other places : they do not start growing till May or June and the cold

weather stops their growth in November ; thus there are only abou six months of vigorous growth.

The water supply is mainly from the rain, but about four time a year irrigation is necessary, the water being supplied from th canal.

The selection work is carefully done and the general arrange ments seemed to be quite satisfactory.

As at other centres experiments are also being made on th manufacture of gur with a view to obtaining a brighter lookin product ; trial was being made of Hibiscus as a clarifying agent This affords a satisfying way of utilising the experimental cane besides showing the local cultivators how to improve their ow product.

Botanical Sub-station.

The Botanical Sub-station has been set up for experiments wit a variety of crops on rather wider lines than usual elsewhere.

The work is carried out by Messrs. Kashi Ram and R. B. Ekbot and the total grant sanctioned is Rs. 2,63,930.

Experiments on Wheat.

These experiments were started in 1930 and their purpose is t test the suitability of the Pusa hybrid wheats, especially the lat maturing sorts, for the cooler regions of the north and north-west.

Some changes in the wheats are also being attempted. The Pus varieties usually grown here are beardless but the cultivators prefer bearded wheat as being less attractive to the numerous birds an other animal pests that steal the grain. Consequently trial is bein made of bearded wheats, and some are being bred for this purpose.

This work is carefully done and should be continued.

Rice.—A collection has been made of strains and varieties of ric from the Punjab and Western United Provinces and 40 pure line have been isolated : some of these are now being tested on larg plots.

Gram.—Improved varieties are sought by selection and hybridi sation.

Other crops are also under experiment.

Karnal has now become an out station of the Central Research Institute at Delhi and the Council has transferred its grant to the Pusa sub-station.

Pusa Sub-station.

Although the main research work of Pusa has been transferred to Delhi it is obviously important to retain a botanical sub-station in north east India and accordingly the Council is maintaining there a Botanical Sub-station. This should also, however, if my proposals are accepted, be taken over by the Delhi Institute.

Agra.

Rusts of wheat and other cereals.

(Visited November 16th, 1936.)

This work was started by Dr. K. C. Mehta, of the Agra College, in 1923, but grants from the Council were first given in 1930-31 for a period of three years : these were subsequently extended. During the course of the investigation a hill station was found to be necessary : a second laboratory was therefore set up at Simla.

The annual grant is Rs. 41,920 with a non-recurring grant of Rs. 9,000 making a total for the three years of Rs. 1,04,980.

Rusts are among the worst of the fungus diseases of wheat, and cause serious losses in all the important wheat producing countries of the world. Three types of rust are common on wheat :

(1) Black rust (*Puccinia graminis* Pers.) which causes serious damage in Australia, Canada and the United States.

(2) Brown rust (*P. triticina,* Eriks.) also common in Australia.

(3) Yellow rust (*P. glumarum,* Eriks. and Henn.) the commonest rust in England, but not found in Australia.

All three attack wheat in India but barley is susceptible to black rust and yellow rust only. The yellow rust is found only in the north, as it cannot tolerate hot weather, while the brown and black rusts occur wherever wheat is grown. These rusts occur in a number of physiological strains differing in their power of attacking the different varieties of cereals, some being much more potent than others. Fortunately only few of them occur in India : 6 out of 144 known strains of Black rust, only 3 of which, however, are widely distributed : 5 out of 65 known strains of Brown rust occur, but only two commonly ; and 6 out of 25 known strains of Yellow rust, but only 3 of these are common : a total of 17 out of 234 known strains. Dr. Mehta attributes this paucity of strains to the rarity of the alternate host plants. barberry and *Thalictrum*, on which new strains have been shown in America to originate by hybridisation.

There is a clearly marked difference between the plains and the hills in the incidence and persistence of rust. In the plains rust does not appear till January or February, although the wheat is sown in October or November, and the conditions throughout the intervening period are favourable to the disease. The infection is therefore late, and obviously not from any local source. In the hills, on the other hand, rust may occur at any time during the growth of the crop and it is always found there earlier than on the plains.

The rust fungi are propagated by spores, which, when ripe, are blown about by the wind. If the spores come to rest on the leaf of a wheat plant, and moisture is present, they germinate and send out a thread-like hypha which penetrates the leaf and so enters the plant. There are several kinds of spores, but the most important for disseminating the disease on wheat are the uredospores which constitute the reddish yellow powder seen in summer on the leaves of infected wheat plants. The uredospores, however, are not very resistant either to heat or cold, and are readily killed by the intense heat of the Indian summer, or by very cold winter weather. A more

resistant kind of spore, the teleutospore, can survive severer conditions but cannot directly infect wheat. The teleutospores of black rust can only infect barberry, and those of brown rust infect *Thalictrum* ; on these alternate hosts a third kind of spore is produced, the aecidiospore, which can infect wheat again.

It had always been a mystery how rust survived from season to season on the hot northern plains where most of the wheat is grown in India. The uredospores are killed by the intense heat of summer and therefore cannot survive in the plains, and other spores seemed ruled out by the absence of the alternate host plants in or near the plains. No alternate host plant for yellow rust is known and the alternate host for black rust, *Berberis vulgaris* and that for brown rust, *Thalictrum flavum*, are found only at altitudes of 8,000—12,000 ft., and are not known to be rusted till March or May, whereas the wheat in the plains is rusted in January.

A study of the occurrence of rust in various parts of India showed that the disease spread from the hill districts, the Nilgiris in the south and Nepal in the north. Uredospores are produced in these districts from September to December : they are blown by the wind and infect first belts of wheat on the foothills, and at a later date, the wheat growing out on the plains. Dr. Mehta has prepared a map showing that in Southern India infection with black rust began in September in the Nilgiri hills, most of the crop being affected : it spread to centres further north where it appeared in January and February. In Northern India infection of brown rust and black rust began in Nepal at the end of December (40 per cent. infection) while in Benares it did not appear till the middle of January.

In association with the Meteorological observatory at Agra he studied the wind currents (following the lines adopted in Canada and the United States) and showed that the winds blowing from the centres of infection were carrying uredospores. Shortly after these spores reached a particular wheat area, the first infection could be found in the crops. The spores were produced in cool conditions and carried by wind at high elevation, so that they escaped the heat and remained viable.

The rusts differ somewhat in their tolerance of hill conditions depending upon their temperature relations : uredospores of yellow rust survive all the year round at high altitudes (above about 7,000 ft.) but they cannot survive the summer at lower altitudes, though they may survive the winter. On the other hand the uredospores of the black and brown rusts can survive the summer at both lower and higher altitudes, though they survive the winter only at the lower altitudes.

This accounts for the occurrence of rust in the plains, but it does not explain how the rusts survive in the two centres of infection, the Nilgiris and the Himalayas. Dr. Mehta has gone into this question of over-summering of the fungus in these regions and concludes that on account of the comparatively cool summer there the uredospores survive on self-sown wheat plants and tillers, which are always present in quantity.

Dr. Mehta suggests that these sources of infection could be put out of action by suspending the cultivation of wheat and barley in

the hill districts for two or three years : in the absence of alternate host plants the fungus would, he states, simply die out. The areas under wheat and barley in the hills are only small but such drastic action is hardly likely to be taken and indeed it might not answer as alternate hosts though not recorded may still be there. Instead of complete prohibition a good deal could be done by prohibiting the April-May sowings in the Nilgiris and the Palnis, and the August and September sowing in the northern hills, and by destroying rigorously the " volunteers " and tillers that appear after harvest. and carry on the rust.

A more feasible method would be to grow only rust resistant varieties of wheat and barley in the hill districts. The breeding of varieties resistant to every one of the prevalent physiological races of rust has hitherto proved impracticable in the United States and Canada, but may be easier in India where so few of the physiological races occur. Attempts have been begun to breed resistant varieties : this work is done at Simla.

As soon as a suitable variety is found it should be brought into general use as speedily as possible. Funds from some Central source would probably be needed for the purpose as the hill districts if they had nothing to gain by the change might feel under no necessity to make it.

Sir Rowland Biffen has observed that small doses of lithium salts enable wheat to withstand rust. Experiments should be made to see if this holds good under Indian conditions, and if so whether it can be put to any practical use.

Dr. Mehta's work appeared to me to be well done and worthy of the support it has received. It is an application to India of the investigations initiated by Dr. Stakman and his co-workers in the United States on Rust epidemiology and Dr. Mehta has shown considerable ingenuity in making the necessary modifications in procedure. He has wisely kept to one problem, and so has been able to make much more progress than if he had scattered his energies in several directions.

Other institutions visited at Agra.

While at Agra I took the opportunity of visiting several other institutions which, however, are not receiving grants from the Council, and therefore are not reported on here.

(1) *The Agra College* : a teaching institution.

(2) *The Upper Air Observatory.*—Here the officer in charge, Mr. Chatterji, explained the method of taking observations at high altitudes by means of kites, balloons etc. At present the practical application of this work for aviation and general weather forecasting but as the investigations develop they may be found to have important bearing on weather forecasting for agricultural purposes and hence the Council should keep itself informed of the progress made here.

(3) *Bichpuri demonstration farm.*—Mr. C. H. Parr, the Deputy Director of Agriculture showed me the various trials going on. One of the most interesting is the growth of berseem as a catch crop on land that would normally be lying idle between the kharif and the rabi crops : this berseem is then fed to buffaloes to increase the milk supply.

(4) *Dyalbagh.*—This colony of the Radhaswami Community was at the time of my visit under the leadership of Sahibji Maharaj Sir Anand Swarup,(1) and it affords an interesting example of a self-contained group of people living in the country in good conditions and supplying a considerable part of their own needs. They are attempting to build up a dairy herd, using Holstein and Scindi cattle as foundation and they have set up a milk factory which is too large for their own herd and can therefore take milk from the surrounding villages. Dr. Wright is reporting on this.

UNITED PROVINCES.

The agriculture of the United Provinces is more varied than in many other parts of India : there is no one dominant crop having the position occupied by rice in Bengal or wheat in the Punjab : there are several crops of considerable importance in the Province, but the distribution is not uniform, and segregation of crops occurs in the different districts. The western part is well irrigated by canals and tube wells : the eastern part is not, but its rainfall is higher : one gains the impression, however, that the country is poorer.

Sugar Cane investigations.

The United Provinces are by far the most important producers of sugar cane in India, no fewer than 1.8 million acres out of British India's total of 3.36 million acres of sugar cane being grown there. But the crop is very localised : it is mainly concentrated in three regions : the Meerut district in the West, Rohilkhand in the Centre, and Gorakhpur in the East. Each of these has a sugar cane experiment station : the chief is at Shahjahanpur in the central district. An important sub-station at Muzaffarnagar serves the western area, and a second sub-station at Gorakhpur serves the eastern region : unfortunately I could not visit this and therefore make no report on it.

The Council has made a grant of Rs. 1,01,260 to be spread over five years for work at the two stations Shahjahanpur and Muzaffarnagar : under Mr. R. L. Sethi, the Economic Botanist to the United Provinces. At the time of my visit, however, the investigations were in the hands of Dr. B. L. Sethi.

(a) Shahjahanpur.

(Visited November 23rd and 24th, 1936.)

Shahjahanpur is situated in the lower lying part of the Ganges plain : it has a moderate rainfall (38 inches in 1934 and 25.7 inches

(1) Sir Anand Swarup died in June 1937.

LIBRARY

in 1935) most of which falls in June, July and August : the highest temperature (about 115°F) is in May and for some 50 days the temperature exceeds 105°F ; the lowest temperature is in January but frost is rare.

The experimental farm at Shahjahanpur is the oldest sugar cane experimental station in Northern India and the most important in the United Provinces. The programme of work includes field experiments and physiological investigations with some chemical control.

Field experiments.

Varieties.—It is not possible to breed sugar cane varieties at Shahjahanpur and in consequence varieties are received from Coimbatore. Of these, Co. 395 and 421 appear to be the best on richer soils and Co. 393 the most generally useful on poorer soils : indeed Dr. Sethi calls it the poor man's cane because it is somewhat thin and is therefore less liable to be attacked by various pests than the thicker canes : further it is drought resistant.

Of the early varieties Co. 350 and 385 are at present the best. They give less yield than the others but they ripen earlier and so they allow of better distribution of the cultivators' time and of course they greatly facilitate the working of the factory. At present the factory pays nothing extra for early canes, but in my view there should be a premium sufficient to make their cultivation attractive.

Both seed and seedlings are received from Coimbatore, and methods have been developed for germinating the seed and raising seedlings here. Any of these that reach the stage of large scale experiment are designated by the letters CoS : several appear to be promising. I was given an interesting table comparing the financial advantage to the cultivator of the new canes over the old desi varieties which easily explained the supplanting of the old sorts by the new :—

	Per canal bigha (⅝ acre).			
	Desi cane.		Improved cane.	
	Rs.	as.	Rs.	as.
Cost of seed, cultivation and manuring	51	6	55	10
Irrigation	7	4	7	4
Rent	10	0	10	0
Total cost	68	10	72	14
Yield, maunds	250		350	
Value of gur, 10% recovery Rs. 3 per maund	75	0	150	0
Profit	6	6	32	2

Manurial trials.—In these experiments comparison is made between organic and inorganic sources of nitrogen : green manure (*sanai*), farmyard manure, and neem cake being the organic, and sulphate of ammonia the inorganic source. The results show that nitrogenous manures increase the yield of cane, but potassic fertilizers do not, although they may effect the sucrose content and the purity

of the juice. The plots without manure yield about 600 maunds of green cane per acre, those with manure yield up to 1,000 maunds.

One interesting result is that green manure supplying about 60 lb. of nitrogen per acre seems to have the same effect as a dressing of 270 maunds of molasses per acre indicating that 1 ton of molasses supplies to the crop 6 lb. of nitrogen, *i.e.*, 0.3 per cent. of its weight. In view of the important problem of molasses utilisation this figure needs confirming.

There are several series of these experiments : they should be continued for two or three years longer and then replaced by a more comprehensive scheme which would give fuller information. A complex factorial experiment containing 3 types of watering (where the mechanical differences are not too great), 3 levels of nitrogen dressings, 3 kinds of nitrogenous manure : tested on 3 varieties would give very complete information as to the different reaction of varieties to differences in manuring and watering (1). A suitable lay-out is given on page 106.

A good deal of analytical work is done on the cane and now that the preliminary tests are over I recommend that the question of sampling be thoroughly investigated. Chemical analysis is worthless, and may even be misleading, unless the sample fairly represents the bulk of the material, and in the case of sugar cane it is difficult to ensure this. The investigation should be done jointly by the Statistician and the Chemist : it would form part of the comprehensive investigation on sampling that I have recommended should be centred at the Delhi Institute.

Physiological Experiments.

The distinctive feature of the investigations here is that they include a physiological section recently started under the charge of Dr. Mathur late of the Imperial College of Science, London, and of the Rothamsted Experimental Station. This work at present consists of two parts : a detailed study in pot experiments of the effects of fertilizers on the growing plant, the lines being substantially the same as those developed by Dr. F. G. Gregory : and a study of the water relationships of the plant. These two problems are ample for one section and I strongly recommend that nothing more be added to the programme.

(b) Muzaffarnagar Sub-station.

(Visited November 19th, 1936.)

This sub-station serves the western part of the province : the upper " doab " between the Jumna and the Ganges, an intensively cultivated region well supplied with sugar factories which stretch in a chain from Saharanpur to Delhi.

(1) For admirable examples of experiments of this type, see the papers of F. Crowther, Bull. No. 25, Tech. Series. Roy. Agric. Soc., Egypt, 1936, " Experiments in Egypt of the Interaction of Factors in Crop Growth, III. The effects of variety spacing, nitrogen and water supply on Development of the Cotton plant and the rate of its absorption of nitrogenous Fertiliser ".

The Station is about 180 miles north west of Shahjahanpur but stands much higher : its climate is drier and more severe : the annual rainfall is about 29 inches and the temperature range is from about 25° F. to 110° F. and in winter frosts are fairly frequent so that the frost resistance of canes can be tested here. The climatic conditions are not unlike those at Karnal, which is indeed is only about 50 miles to the west.

The farm has been established for some time but the Council's sugar cane experiments were started only in 1934. The two main purposes are to test canes received from Coimbatore and Shahjahanpur so as to see how far they are suited to this Gangetic canal area. Co. 385 appears at present to be the best early cane ; Co. 312 the best medium cane under moderate conditions of soil, irrigation and manuring ; Co. 421 and 331 seem promising in richer conditions, while Co. 331 seems better in water-logged soils.

Search is also made for good late varieties of cane but the local agricultural conditions are not at present very suitable for these, since the harvesting clashes with the harvesting of wheat. Moreover it is not yet clear that the factories would find later crushing profitable : their officers state that they have no control over the harvesting and high yields of immature cane are likely to be obtained by the grower and passed on to the factory. In spite of these difficulties, however, the production and selection of late canes must be continued: if later canes are to be grown at all the cultivator must obviously have the most profitable.

Mr. P. W. Marsh, the Commissioner for the Meerut Division, told me that the work done in the province on sugar cane varieties has got through to the cultivator so effectively that nearly the whole area is now under improved varieties.

Fertilizer Experiments.—These are on similar lines to those at Shahjahanpur and the results up to the present are of the same order, though only two years data are available, the 1933-34 crop having been largely destroyed by insect pests. The maximum effect is obtained with 60 lb. nitrogen per acre. Molasses applied as fertilizer gave the same results as an equal weight of farmyard manure, both being applied at the rate of 200 maunds (about 7 tons) per acre. Neither potassic nor phosphatic fertilizer increased the yields in these experiments.

The purity of the juice differs in the different varieties, but it tends to be lowered by nitrogenous manure.

The green manure experiments show that *sanai* increased the yield of cane, and that it can conveniently and advantageously be grown after cotton and before sugar cane, instead of leaving the land bare as at present : this sequence : cotton : sugar cane, is not unusual in this region.

Other experiments deal with times of sowing, spacing, times of applying fertilizers, and various modes of irrigation. Five irrigations seemed to give the best results : 80,000 to 120,000 gallons per acre had been given to the highest yielding plots.

Entomological Investigations.

These are a special feature of the work at Muzaffarnagar : they are carried out by Mr. R. P. Gupta. Insect pests in these western districts of the United Provinces appear to be worse than elsewhere and with the spread of sugar cane cultivation the problems of pests and diseases have become still more serious. I was informed that in 1934-35 most of the factories in the Meerut division had to close down early in the season on account of poor deliveries of sugar cane. There were heavy infestations by the Stem Borer (*Argyria sticticrespis*) before monsoon rains, by the Top borer (*Sciropophaga nivella*) after monsoon rains by the Root borer (*Emmalocera depressella*) in August, by the leaf hopper and by the *Pyrilla* and white fly from the commencement of monsoon rains till the beginning of winter, in addition to attacks of termites. Something like a quarter of the crop was destroyed by stem borer in June before the actual cane formation began, and by harvest time the remainder suffered 50 per cent. or more infestation with top borer, in addition to the damage done by pyrilla and white fly.

Varieties differ in their susceptibility to attack and it is always possible to select canes less liable to suffer than others growing near to them. It remains to be seen how far this is a practicable method of control : if only a few growers used the less susceptible canes they might escape, the insects preferring the more susceptible varieties grown by their neighbours. But if all the growers in a particular region grew the less susceptible canes the insects might simply adapt themselves to the change and for want of anything better attack the new canes. That, at any rate has been the usual experience elsewhere.

The programme of investigations includes (*i*) the study of alternative food plants from which infestation is possible ; (*ii*) the relation of time of planting to incidence of pest attack ; (*iii*) the relation of germination, tillering and growth to pest attack ; (*iv*) the behaviour of different varieties of cane.

It is very desirable to investigate fully the conditions under which the insect pests multiply and do damage. Spraying and direct control methods are impracticable and breeding of resistant varieties is of limited application. but a knowledge of the conditions under which damage is done may enable the agriculturist to advise as to methods for reducing loss to a minimum. Phosphatic fertilizers appeared to decrease susceptibility to attack by the top borer, but on the other hand waterlogging of the soil appears to increase the susceptibility. Second or third year ratoons harbour pests badly.

Various parasites of the borers have been found parasitising either the egg or the caterpillar. but it remains to be seen whether they can be made to play any important part in control. Some control of leaf hoppers (*Pyrilla*) was effected by collecting the adults and the nymphs in hand nets from the young crop and also by collecting egg masses from April onwards. and stripping and removing the dry leaves each month from September onwards.

NOTE BY MR. F. YATES, HEAD OF STATISTICAL DEPARTMENT ROTHAMSTED EXPERIMENTAL STATION.

Design for a combined experiment on varieties, quantities and forms of Nitrogen, and their interaction with irrigation.

Four Course Rotation, including two years Sugar Cane.

It is recommended that a factorial design including all combinations of three varieties, three levels of irrigation, three levels of Nitrogen and three forms of Nitrogen be adopted. This will give 81 treatment combinations, which can conveniently be arranged in a 9 × 9 quasi-Latin square in which the whole of each row is subjected to the same irrigation treatment. A square of this type is shown in the accompanying diagram, *a*, *b* and *c* being the three levels of irrigation, and *p* *q*, and *r* the three varieties ; the numbers 1—9 indicate the quantity and form of Nitrogen according to the tables :

quantity.

	n_0	n_1	n_2
S. A.	1	4	7
Cake	2	5	8
F.Y.M.	3	6	9

Thus 8 represents the double dressing of cake.

b	r8	r3	q1	q5	q9	r4	p7	p2	p6
a	r6	r7	q8	q3	q4	r2	p5	p9	p1
a	q2	q6	p4	p8	p3	q7	r1	r5	r9
b	q4	q8	p9	p1	p5	q3	r6	r7	r2
c	r1	r5	q6	q7	q2	r9	p3	p4	p8
c	p5	p9	r7	r2	r6	p1	q4	q8	q3
a	p7	p2	r3	r4	r8	p6	q9	q1	q5
c	q9	q1	p2	p6	p7	q5	r8	r3	r4
b	p3	p4	r5	r9	r1	p8	q2	q6	q7

If the lowest level of *n* is zero then treatments 1, 2 and 3 will be identical. If desired the levels of farmyard manure may be higher than sulphate of ammonia and cake, *e.g.*, farmyard manure at 0, 60 and 120 lbs. N. per acre and sulphate of ammonia and cake at 0, 40 and 80 lbs. N. per acre.

Study of the above design will show that all combinations of any two factors (except irrigation) occur once and once only in every row and every column. Thus the effect of any one factor (except irrigation), averaged over all levels of the other factors, is free from all row or column effects : the same applies to all interactions between two factors (including irrigation).

The advantages of factorial design are considerable in such a case as the present in which irrigation is likely to affect both the response to Nitrogen and the difference between varieties, and in which the different varieties are likely to respond differently to different quantities and forms of Nitrogen.

The experiment should clearly be a permanent one, being carried on for several years on the same plots in order to measure cumulative effects. As in all Rotation Experiments it would be best to

have one set of plots in each phase of the experiment, *i.e.* four 9 × 9 squares in all at each place. A reasonable compromise in this case, however, would be to use two 9 × 9 squares started at twoyear intervals. Thus one square would be under sugar cane in every year. A set of such trials carried out simultaneously at three or more centres would make a really good experiment. In laying down additional squares either at the same place or in different places the *square given above should be re-randomized by rearranging first the* row (including irrigation treatments) and then the columns amongst themselves in random order. It will also be better if the four different keys given below are used in turn for the numbers 1—9. These keys being :

—	I			II			III			IV		
	n_0	n_1	n_2	n_0	n_1	n_2	n_0	n_1	n_2	n_0	n_1	n_2
S. A. ..	1	4	7	1	7	4	1	3	2	1	2	3
Cake ..	2	5	8	3	9	6	4	6	5	7	8	9
F. Y. M. ..	3	6	9	2	8	5	7	9	8	4	5	6

Methods of computation are given in : Imperial Bureau Soil Science, Technical Communication 35. " The Design and Analysis of Factorial Experiments ". F. Yates. (In the Press).

Cawnpore.

Research and Testing Station for the Indigenous System of Gur *and Sugar Manufacture.*

GRANT : Rs. 1,67,380 to be spread over 5 years.

In spite of the great developments of the cane sugar industry something like 80 per cent. of the sugar cane grown in India is worked up in the villages either into Gur or Khandsari sugar. The processes are very wasteful ; the mills are inefficient and the recovery from the cane does not usually exceed 60 per cent. of the total sugar present. It is of course impossible to hope for the high standard of efficiency attainable in a well conducted factory, but there is room for considerable improvement on the present methods.

A station has therefore been set up at Bilari in the Moradabad district with the purpose of improving the village processes, and it is proposed to study the possibility of using small vacuum pans in the village factories and of improving in other ways the making of gur and sugar.

A somewhat similar investigation is being carried out at Patna, but on a much smaller scale.

I had no opportunity of seeing this work but I recognise its importance having seen a good deal of the making of Gur in the villages.

Improved Juice Boiling Bel.

GRANT : Rs. 3,440.

This work was carried out at the Nagalia farm of Lala Har Sahai Gupta ; it is purely technological, and I am not in a position to express an opinion about it.

SUGAR RESEARCH INSTITUTE.

The Harcourt Butler Technological Institute, Cawnpore.

(Visited February 10-12th, 1937.)

This Institute, opened in 1921, adjoins the Agricultural College. It has four departments : General Chemistry, Oil, Sugar and Leather.

As soon as it was decided to develop the sugar industry of India, it was recognised that investigations would be needed on the technological just as much as on the agricultural side, and that sound disinterested advice must be available for the factories. Further, it was necessary to set up standards for different grades or qualities of the sugar and to arrange for specifications to which the factories must conform.

Accordingly the Council set up a Sugar Research Institute and placed it at the Harcourt Butler Technological Institute. The decision was sound, as the Institute has good facilities for technological work and has acquired experience in connection with other industries. These technological investigations should at an early stage be handed over to a Central Sugar Committee.

The Director of the Sugar Research Institute is Mr. R. C. Srivastava and the Staff consists of a Professor of Sugar Engineering now being selected ; the Professor of Sugar Technology, Mr. Van der Meyden, a very competent Dutch expert who has come here from Java ; four assistant Professors and two research chemists. The Statistical Assistant is Mr. P. V. Sukhatme.

Experimental Sugar Plant and Training of Candidates.

GRANT : Rs. 2,25,000 spread over 5 years.

The duties of the sugar technologist are to advise sugar factory owners on difficulties that have arisen in the course of their work, to advise promoters of new sugar factories in regard to the selection of the site, the lay-out, machinery, etc., and to carry out experimental work with the object of improving factory practice. In order that this may be done effectively an Experimental Factory has been set up at the Institute where factory problems can be studied on a semi-commercial scale.

Provision has also been made for the training of sugar technologists. Students are received from all parts of India but the Government of the United Provinces has the first claim to 20 per cent. of the places.

A Bureau of Sugar Standards.

GRANT : Rs. 32,610, spread over a period of 5 years.

It is impossible to establish the sugar industry on a sound basis in India unless standard grades of sugar can be agreed upon and duly specified. For this purpose a central body is obviously necessary and the Council has made provision for the establishment of a Bureau of Sugar Standards at the Sugar Institute.

The functions of the Bureau are :—

1. Preparing and supplying sugar standards.
2. Maintaining a Museum of supplies of sugar and other sugar products.
3. Publishing annual reviews dealing with the quality of Indian sugars and of competitive foreign sugars.

As soon as the procedure and methods have been worked out the Bureau will become an administrative rather than a research organisation and it should therefore no longer be supported out of the Council's funds.

Statistical Branch.

The statistical work of the Institute falls into two parts :

1. the collection of statistical data in regard to the industry :
2. advising in regard to the design of experiments made in the factories on various technological problems.

In order to avoid the possibility of apparently conflicting advice, designs of experiments should be circulated to the Council's Statistician and to Professor Mahalanobis for information and comment.

Utilisation of Molasses.

Approximately half a million tons of molasses are produced annually in India, and it is important to find some method of utilisation.

Four methods are being studied :

(1) *For surfacing metalled roads.*—Considerable lengths of roads have been treated and the results seem promising, but it remains to be seen how long the effect lasts.

(2) *As fertilizer.*—Experiments in several of the agricultural experiment stations have shown that molasses has distinct value as fertilizer in some circumstances, though not in others. Successes are recorded at Shahjahanpur, Muzaffarnagar, Nagina and Bangalore ; on the other hand, negative results were obtained at Padegaon and Risalewala.

(3) *Conversion into industrial alcohol.*—At first sight this is the simplest method of handling the molasses, as it could be done at the sugar factory, and would help if the

spread-over of the work ; it requires no new organisation but only an extension of the existing factory organisation and it presents no specially difficult problems to the technologists, suitable methods being already well known. Indeed it is understood that the Government Central Distillery, Nasik Road, contracts for the whole of the molasses of some of the sugar factories. There are, however, economic and excise difficulties in the way of unlimited extension of this method.

(4) *Preparation of a cattle food.*—A grant of Rs. 10,000 spread over 2 years has been given for investigating this possibility, the trial foodstuffs being prepared at the Institute and tested at several of the northern agricultural experimental stations.

Bagasse screenings from the cane are dried and mixed with boiled molasses and sources of protein such as Chuni, mustard cake or ground-nut cake, then pressed into cakes. These contain approximately 17 per cent. protein and 62 per cent. carbohydrate. No feeding results are available as yet, but European experience with this type of food shows that it can be made to give very good results.

Other possibilities.

Another method which I suggest should also be tried is to utilise the molasses for growing yeast. Some of these are good cattle food ; they are rich in protein and other valuable mutrients and there should be no difficulty in growing them at the factory. This method was used in Germany during the war and is attracting attention again, now that the policy of national self-sufficiency is developing.

At the sugar factory in Mysore remainder yeast grown in molasses was readily taken by farmers, (1) and it seems desirable to experiment with other types also.

In western countries molasses added to grass or other green fodder as it is put into the silo improves the quality of the resulting silage. Experiments on these lines should be tried.

In western countries also molasses has various other industrial purposes : it is used for making solvents and the shock absorber and " antifreeze " fluids associated with the motor car industry : as yet these uses are unimportant in India.

Oil Section.

GRANT : Rs. 90,000 for 3 years.

The work of this section consists in training students, in rendering technical assistance and advice to the industry and in carrying out investigations of technological importance, such as the bleaching of certain oils for technical use. The Council has decided to hand over this subject of Oil Technology to the Industrial Research Bureau, a decision in which I entirely concur.

(1) For American experience with this kind of yeast, see Broughton and Fry, Maryland Agric. Expt. Sta. Bull., 349.

Cotton-seed crushing : supply of decorticated cake for education and propaganda.

GRANT : Rs. 10,000 spread over 3 years.

This work is not yet begun. Its purpose is to take over decorticated cotton cake made at the Harcourt-Butler Technological Institute, and supply it to the Officers of the Agricultural Departments, for use in experiments and demonstrations on departmental farms.

At the present time the large amount of cotton seed produced in India is not fully utilised. A little is exported to Great Britain and other countries as raw material for the oil and feeding stuffs industries, but nearly all of it is fed direct to cattle, which involves wasting a good deal of the oil. The establishment of an oil industry in India would necessitate the creation of a market for the decorticated cotton cake and this requires much preliminary demonstration work among farmers.

Oil seeds crops are studied at the Cawnpore Agricultural College with a view to classification and improvement. The work is in some respects similar to that being done at Lyallpur and the workers should keep touch with one another.

Nagina Rice Research Station. (United Provinces.)

(Visited November 22nd, 1936.)

Paddy occupies 6½ million acres in the United Provinces principally in the northern and eastern parts and the early varieties in particular are widely cultivated.

In spite of this large acreage, however, the United Provinces do not produce all the rice consumed, and there is in consequence an importation which the Department is trying to avoid by increasing the production in the districts irrigated by the recently constructed Sarda Canal.

The experiments are in general charge of Mr. R. L. Sethi, Economic Botanist (Sugar Cane and Paddy) to the United Provinces Government ; the local officer is Dr. B. L. Sethi, the Assistant Paddy specialist, with two research assistants, Messrs. T. R. Mehta and P. S. Gupta : the farm superintendent is Babu Sanjai Singh. The amount of the Council's grant is Rs. 1,39,660, spread over five years.

The Nagina farm was established in 1932 as the paddy breeding station of the United Provinces : it is about 50 miles east of Muzaffarnagar almost in a line with Karnal which lies 50 miles to the west. It is a district well-known for its early types of rice, including Basmati, claimed as the best table rice in India. It is about 344 miles from another rice experiment station, Kala Shah Kaku in the Punjab.

The work consists in seeking for early varieties of good yield and high quality. This necessitates the possession of a considerable collection of strains and fortunately one had already been started in the United Provinces by Mr. R. L. Sethi in 1924 : he collected some 1,200 samples from the different regions and from these isolated 135

types possessing constant characters. Others have since been addc. to the collection and now a considerable number of strains are grown at Nagina. The importance of earliness arises from the circumstance that rice is a kharif crop, sown in June or early July before the rains, and harvested from September to December according as the variety is early or late : if it can be cleared by October gram can be sown as a rabi crop : if by November, wheat or peas can be sown, but if it remains on the ground till December nothing can be sown and the land must be left idle till the following June, unless a green manure crop, *sanai*, can be sown in April or May. The sowing of an early variety therefore permits the growing of a rabi crop.

On the other hand late varieties give 10 to 20 per cent. or more higher yield than do the early varieties, and there are regions, *e.g.*, the submontane regions liable to flood and the eastern districts, where late varieties alone can be cultivated.

A further advantage of the early varieties is that they commonly escape the serious pest *leptocorisa varicornis*, locally called Gandi, which from mid August to mid October, but especially during September, attacks any young grain that is still in the green milky stage.

Earliness, however, does not invariably ensure immunity from Gandi : late varieties sometimes escape more completely through not being sufficiently advanced at the time when the insect is ready.

The only immune rice is the local *Sathi*, (60 day), a poor yielding early sort but with the great advantage over the good commercial varieties that the panicle is enclosed so that the insect cannot penetrate to the grain. This *Sathi* was crossed in 1929 with better yielding varieties so as to obtain new sorts combining high yield and good quality with the enclosed panicle and consequent immunity to *Gandi* The F. 5 generation has now been obtained, and has yielded cultures, apparently fixed and pure, in which the panicle remains enclosed during the green milky stage and then opens out giving grain in large quantity and of high quality.

In connection with this selection and hybridisation Dr. Sethi has been intermittently carrying out cytological investigations. It is unreasonable to expect results in these conditions and if he is staying on I should recommend the appointment of a special assistant trained in cytology to do the actual work.

There are a number of manurial experiments which are well designed and well laid out. They show the value of green manuring with Sanai : this is superior to sulphate of ammonia which in turn is superior to nitrate of soda. Other experiments deal with the time of planting, varying also the age of the transplanted seedlings ; these indicate, as usual, that the late varieties ripen at roughly the same time whenever they are sown, *i.e.*, their time of ripening is fixed ; while the early varieties ripen earlier or later according to the time of sowing, *i.e.*, their period of growth is fixed. Earlier ripening of early ripening varieties can be secured by earlier sowing, but earlier ripening of late varieties cannot. Experiments are being made to see if earlier ripening can be obtained by vernalization, but so far the attempts have been without success.

The troublesome problem of the shedding of rice at harvest time, the result of each separate grain being on its own little stalk, is under investigation. The character is varietal and is probably controllable.

As happens not infrequently, the yields obtained on the farm here are 35—45 maunds per acre as against the peasants' yield of 15—20 maunds for early sorts and 25—30 maunds for late sorts. For wheat the yield on the farm is 20—25 maunds per acre as against the peasants' average of 11.

Work is also in progress on the hulling and cooking quality of rice and on the possibility of improving the storage. Consumers prefer rice that has been stored for some months and will not eat new rice if they can afford the older grain. A considerable quantity of rice is held in the villages and bazaars in tins, boxes, gunny bags, earthen jars, etc., for periods up to three years. Attempts are being made to improve the storage. This part of the work, particularly that dealing with hulling and cooking quality, is necessarily vague and indefinite and should be regarded simply as a minor adjunct to the breeding and selection.

The field work is well carried out. The records are elaborate and their collection takes up much of the time of Dr. Sethi and Mr. Mehta, with such assistance as they can get from their small staff. This is inevitable. But they are in addition called upon to work out the detailed computations involved in the statistical calculations. This is an uneconomic use of their time, and it would certainly be an advantage to give them help on this computing side. I understand that graduates could be obtained at a relatively low salary who would be sufficiently trustworthy and who, if provided with a hand calculating machine, could do all the necessary calculations.

It would also be an advantage to appoint an analyst who could under direction follow the changes in nitrate and ammonia content of the soils of the more important plots during the year : this might furnish the clue to some of the differences obtained in different years on the manurial plots.

The Council, has no experiments in the eastern part of the province.

Barley.

The barley grown in India is almost entirely 6-rowed : the 2-rowed varieties which are usually in larger demand for brewing do not as a rule give sufficiently good yields to justify their growth. Barley is almost entirely confined to Northern India, and out of a total of 6½ million acres, more than 4 million are grown in the United Provinces and nearly 1½ million in Bihar and Orissa ; over 600,000 acres are grown in the Punjab and 130,000 acres in the North-West Frontier Province. Much of its importance lies in the circumstance that if well suited for malting, it commands a price far higher than it could obtain if sold for food, the difference being sometimes as much as 50 or even in special cases 100 per cent. Assuming prices of this order could be obtained, barley would

make a good cash crop, as it can be grown in the rabi season and without much expense.

For many years barley has been exported to England and samples have been periodically purchased by maltsters. But they had several defects : rather poor quality, serious contamination with weed and other seeds, and they have of late years been infested with the Khapra beetle, *Trogoderma granarium*(1), which if introduced into maltings in England, causes very serious trouble In all the above named provinces experiments have been made for the improvement of barley varieties, and, in order to ascertain whether the new sorts were better than the old, a number of samples of barley were sent from the Experiment Stations to the Institute of Brewing, London, and examined by their experts. The reports showed that some of these samples were distinctly better than the usual market supply and if available in commercial quantities would probably find a ready sale.

In 1934, the Council made grants to the Departments of the above three provinces : Rs. 6,000 each to the Punjab, Bihar and Orissa and Rs. 4,600 to the United Provinces, to run over a period of 3 years for the continuance of this work. A considerable number of samples have been examined under this arrangement and the general trend of the reports is that while they do not come up to the high class English 2-rowed barleys, some would compare favourably with the 6-rowed Californian barleys, of which a considerable quantity is used in English breweries, while others of lower grade would be acceptable to distillers. The price obtained for the Californian barley is well above that for feeding barley, though not usually as high as that obtained by the first class samples of English malting barley.

The two types of barley, 2-rowed and 6-rowed, are not interchangeable and serve somewhat different purposes in the brewing process : somewhat different properties are therefore required Many brewers recognise in the Californian 6-rowed barley something which they call " sun " which they consider can be obtained only in countries where the crop has been grown in full sunshine ; further, the fibre in the grain either by virtue of its amount or of some special property facilitates work in the mash tub. Whatever the Californian properties may be, however, the experts of the Institute of Brewing find that the best of the Indian barleys sent recently possess them to a considerable degree so that some of the recent samples compare favourably with the best imported Californian barley.

Most of them, however, are not quite so attractive in appearance as the best Californian samples. The difference is largely on the surface, for the reports repeatedly state that the malt was better than had been expected from the appearance of the barley The proteins in Indian barley apparently have less harmful effects on malting quality than those of the ordinary English or Californian barleys ; the Indian barleys modify better and yield higher extract than these other barleys of similar nitrogen content. Clearly in purchasing Indian barley the standards would

(1) This is the name usual in the publications of the Imperial Entomological Institute, but *T. khapra* is commonly used in India.

have to differ from those used in purchasing Californian barley. A little time would probably be necessary to allow the brewers to adapt themselves to these differences in appearance and constitution, and so long as Californian barley remains available in large quantities, it would probably be preferred by the average buyer, partly because the staff know how to deal with it, partly because of its better appearance.

There are, however, indications that Californian barley is not likely to remain in its present important position in the English market. Now that prohibition is repealed in America, the manufacture of beer is developing, and the demand for Californian barley is increasing both in the eastern and western States. In any attempts to take the place of Californian or Mediterranean barley the Indian barley would have a substantial price advantage in the 10 per cent. *ad valorem* duty imposed on non-Empire barleys, from which India is exempt, and moreover there are many brewers who would like to announce that theirs was an all-Empire beer. It is reasonable to expect that these factors should help materially in substituting Indian for Californian barley on the English market, if on its merits it deserved the place. The only important competitors so far are the Australian 6-rowed barleys, some of which are like the Californian, and those grown by British farmers who are now experimenting with 6-rowed barleys with a view to securing this market themselves. Suitable varieties hardly exist at present, but will possibly be found; it remains to be seen, however, whether the necessary qualities can be obtained in a season of but little sunshine.

It is difficult to say how large this market might become. At present well under one million quarters (=200,000 tons) of Californian barley are used annually, and it is improbable that the whole of this could be replaced. Up to the present C.-251 has been the best of the United Provinces' barleys, and there is little question that if consignments like the samples recently sent from Raya (Muttra) (1936 crop) could be supplied in quantity, they would find a ready market. But this same variety grown elsewhere was not so successful, and clearly the soil and climatic conditions play an important part.

Other samples were considered by the experts to be comparable with Chilian forage barleys which, while used by some maltsters in England, do not command such high prices as Californian.

I recommend therefore that the efforts for improvement should be concentrated on the 6-rowed barleys with a view to capturing the share of the market at present held by Californian barleys.

Unfortunately there is no simple test that can be applied locally and in consequence it will be necessary for some time to come to send samples to the Institute of Brewing for valuation. The nitrogen percentage and Bishop's Extract Scale(1) give a first approximation but if the work is being developed, it seems desir-

(1) Journal Instit., Brewing, 1936, Vol. 42, p. 107.

able to send an officer to England to study the market requirements so that he could make the first selections in India. It would, still be necessary to send the final samples to the Institute of Brewing before recommending their multiplication on a large scale. It must be emphasised, however, that no permanent trade in Indian barleys can be developed until the shipments can be guaranteed free from Khapra beetle.

There is a certain demand in India for malting barley, and some districts, such as Rewari and Farrukhabad in the United Provinces, are already well known in India for supplying good samples. The possibility of manufacturing malted foods should also be examined.

Fibre Plants.

Sunn Hemp, Cawnpore.

GRANT : Rs. 34,226 for 3 years.

Schemes dealing with Sunn hemp are in progress in the United Provinces, Madras, Bombay, Bihar and the Central Provinces, the general programme being similar at all the centres, though there are differences in detail. As the United Provinces are the chief producers and exporters of raw hemp in India special stress is laid on the retting and the treatment of the fibre. Preliminary experiments show that the existing methods can be considerably improved and the resulting fibre is worth much more than that now produced.

Utilisation of Linseed Fibre.

GRANT : Rs. 33,000 to be spread over 3 years.

The work has not yet begun.

In flax growing countries it is recognised that the production of flax cannot be combined effectively with the production of oil, as no variety of linseed is known which possesses the triple qualifications of producing high yield of oil, high yield of a good flax fibre, and good agricultural properties. The Indian oil varieties, however, produce a short fibre for which it is believed a market can be found. The purpose of this investigation is to investigate the possibility of extracting this fibre thereby making the crop more profitable.

If a definite outlet is found for the fibre this work could be undertaken, but if not, I recommend that the scheme be dropped.

The Cawnpore Agricultural College.

While at Cawnpore I took the opportunity of visiting the Agricultural College, an active institution where much teaching is done. It is claimed that an important percentage of the students go in for practical farming after they have completed their course.

The Experimental Farm.

(Visited, February 10th-12th, 1937.)

A large area is under experiment and an extended programme is carried out under the efficient supervision of Mr. P. B. Richards.

While here I saw the sad sight of a large area of arhar cut down by frost. It is rapidly becoming possible to issue frost warnings by wireless and it seems desirable to experiment with smudge fires and other devices for minimising frost damage, so as to see if they have any economic value in these regions liable to frost.

Fruit Research : Chaubattia Station.

It has long been known that fruit would grow well in the Kumaon Hills, and as long ago as 1870 a Government Orchard was started at Chaubattia ; others followed. Then, for a time, interest died down : it revived, however, with the development of cheap and relatively rapid motor transport, and from 1915 fruit growing became more active and the orchards are now increasing in number.

All the ordinary English fruit can be grown here and there is reason to believe that a good fruit industry could be developed.

The old Government fruit farm has now become the United Provinces station for research on temperate fruits and a grant of Rs. 1,60,780 spread over 5 years has been given. I was not able to visit it but reports on the work were submitted.

The soil investigations include studies of the suitability of the different soil types for different varieties of fruits, and attempts to trace out any connections that may exist between soil conditions and incidence of diseases.

The entomological work consists largely in making a tree by tree survey with the purpose of acquiring a detailed knowledge of the incidences of pest attacks and correlation of these with soil conditions. This method seems to me to be very sound and likely to give valuable results.

The Mycologist is studying certain specific diseases : collar rot of apples, etc.

The horticultural experiments include search for suitable apple stocks, methods of propagation and management, pruning, mulching, etc.

As far as it is possible to judge from the reports the lines of work seem to be satisfactory.

Light traps.—An experiment with light traps made at Ramgarh in 1932 was unsuccessful ; out of 224 adults attracted to light only 14 were females, the rest being males. This is a common occurrence. Dr. C. B. Williams at Rothamsted has, however, recently found that for certain moths in England the proportions of males and females captured depends on the height

at which the trap is placed ; a higher proportion of females is caught with a trap at 35 feet above the ground than in one at 4 feet. If light trapping is practicable. then the effect of setting at higher level should be tried.

Lucknow.

(Visited, February 15th, 1937.)

Lucknow University, Botanical Department, incharge of Professor B. Sahni, F.R.S.

Professor Sahni's investigations in paleo-botany and the borderland between geology and botany have given to the Botanical Department of the Lucknow University a high reputation, which the standard of work in the various sections fully justifies. None of the work is definitely agricultural, and there is no scheme fostered by the Council, but the Department is too good to be omitted from this list.

Dr. S. C. Varma has made some interesting ecological studies of the upper Gangetic flora and traces the seasonal change of flora from tropical to temperate and to desert conditions during the course f the year. This seasonal variation of climatic factors is so great that no species is likely to remain dominant throughout the year. Dr. M. P. Chowdhury is in charge of physiological investigations, Dr. S. P. Pande carries out morphological studies and is surveying the liverworts. while Mr. A. R. Rao is making anatomical studies.

Professor Sahni's laboratory is so well organised and he himself is such a capable investigator that some further development of his work could well be encouraged. He considers that surveys of the various groups of the Indian flora would be of great scientific value. He points out, for example, that the fungi have never been adequately surveyed, and many of the groups also lack proper description. It could not be claimed that the work would be of practical value, but it would serve a useful purpose in the training of students and in the development of the careful critical habits of mind which are so rare, and yet so essential to good research.

Allahabad.

(Visited, January 15th and 16th, 1937.)

Dr. N. R. Dhar has in the past ten years published a large number of papers on the transformations of nitrogen compounds in soil and he has recently put forward the idea that some of the changes are produced, not by bacteria as was formerly supposed. but by sunlight. Other investigators in India, however, have been unable to find any evidence of this photochemical change. There is nothing inherently improbable in Dr. Dhar's claim : the question can be settled only by experiment, and only in tropical or sub-tropical countries. The Council has given a grant of Rs. 9,360 to be spread over three years from January 1936.

These questions are of purely scientific interest and the investigation is therefore quite properly carried out at the University of Allahabad.

Dr. Dhar is also studying the changes in nitrogen content of the soil consequent on the addition of molasses. He confirms the result already obtained by some, but not by all workers, that both the ammoniacal and the total nitrogen are increased, and he discusses the mechanism of the process and the relative parts played by light and by micro-organisms.

While at the University I took the opportunity of visiting the laboratories of Professor Saha, whose researches in Physics are well-known.

The American Presbyterian Mission.

I visited also the Agricultural Institute of the American Presbyterian Mission where I saw an admirable demonstration of the reclamation of eroded land. By skilful bunding Dr. Sam Higginbottom has succeeded in restoring a considerable area of land that had been destroyed by flood, and in so arranging the bunds that similar catastrophes are unlikely to occur in future. The demonstration is worthy of careful study and of repetition elsewhere.

Other demonstrations include the production of fodder stuffs for dairy cattle and the general improvement of the dairy herd which, however, lies outside my province.

Benares.

(Visited, February 13th, 1937.)

GRANT : Rs. 67,920 spread over 5 years.

Institute of Agricultural Research (Benares Hindu University).

The work here is in charge of Dr. B. N. Singh, Kapurthala Professor of Botany. The Institute is unusually well equipped with modern plant physiological appliances, which were demonstrated to me by the assistants and the students. The work done under the Council's scheme consists in—

(1) a physiological analysis of the effects of fertilizers on the growth of the sugar cane : this includes studies of the growth and sugar content of sugar cane in relation to the absorption of nutritive elements, and of the effects of hydrogen ion concentration on growth.

(2) a study of the effects of soil and climatic factors on the growth of wheat, and the relation of soil, nitrogen and moisture content to the protein content of the grain.

In practice this means the application to sugar cane and to wheat of all the ordinary plant physiological exercises. The present work is confined to the laboratory, but it is hoped later on to make field experiments.

In view of the wide range of work in the department, it would be unreasonable to expect detailed critical examination of methods or appliances : these tend rather to be accepted without making full examination of their validity. The chief value of the work lies in the training it affords to the men who are doing it ; they learn how to handle apparatus and they know whose method they are using, while the variety of work going on in the laboratory gives them a wide training and prevents them becoming too narrow in their outlook. The training would be improved if the students were taught the use of valid statistical methods, not as subject, but as an integral part of their physiological experiments. In view of the fact that the University has a strong mathematical staff this should present no difficulty.

THE PUNJAB.

The Punjab falls into three agricultural divisions : the hill districts to the north, where grazing and soil erosion furnish difficult problems for the agricultural, the livestock and the forestry departments : and where also fruit culture is possible : the irrigated regions where wheat is the dominant crop but oil seeds, sugar cane and cotton are also important ; and a southern dry region where dry farming is practised.

The Punjab is characterised by the diversity of its agriculture and in two respects it occupies a leading position : it has the largest acreage in wheat and in fodder crops of any province. One of the results is that milk is more widely used here than in most other regions. Wheat is the most important crop in the province, occupying 9 out of 26.5 million acres net area sown, and fodder crops come next with an area of 4.8 million acres ; this is a larger area than in any other province.

The Council's schemes in the Punjab are concerned chiefly with wheat, fruit and oil seeds. The agricultural investigations are centred at the Agricultural College, Lyallpur ; grants are given for some scientific investigations at the Punjab University, Lahore ; and important investigations are carried out under the aegis of Punjab Irrigation Board at the Irrigation Research Laboratory, Lahore. The Agricultural Department also carries out a large amount of work.(1)

Lyallpur Agricultural College.

(Visited, February 6th, 7th and 8th, 1937.)

The College was started in 1909, and many investigations in agricultural problems affecting the Punjab have been made there. It is now one of the great centres of agricultural research in India.

(1) An official publication " Department of Agriculture, Punjab ; Summary of the more important results arrived at or indicated by the Agricultural Stations and Research Officers in the Punjab, 1936 " gives a useful summary of the work done at the various stations with sufficient detail to enable experts to study the results.

Wheat Investigations.

These are confined to studies of the milling and baking qualities of the different varieties of wheat. Unfortunately no simple chemical determinations give sufficient information about these qualities : direct milling and baking tests are necessary for which special and rather costly equipment is required.

The Council has given a grant of Rs. 22,300 towards the establishment at Lyallpur of an experimental plant for carrying out milling and baking tests of wheats produced in the Punjab and other provinces. It is proposed to send the baking specialist to America for training there.

It is very desirable at the outset to agree on the purpose for which the wheat is required. Different markets have different requirements, and it is essential that the person in charge of this work should know definitely for which market he is to cater.

In view of the fact that most of the wheat consumed in India is probably made into chapatis, there should be an inquiry into the characters needed to give the best results. If, on the other hand, the wheat is being bred for export to Great Britain, then the requirements of the English miller must be carefully studied : samples should be sent for report to the Miller's Research Institute, St. Albans, if this Institute can continue to undertake this work.

Fruit Investigations.

1. Citrus Stocks and Grape Vines.

Grant : Rs. 57,430 to be spread over 5 years.

This scheme is under the charge of Sardar Sahib Sirdar Lal Singh who has an expert knowledge of fruit growing gained in California : it is complementary to that of the Central Provinces, and deals with the Santra type of oranges ; mainly with Maltas. Seeds of numerous varieties obtained from the Punjab and outside regions have been sown and the seedlings and resulting trees will be studied. Useful stocks will then be multiplied and distributed. Stocks of the Santra types grown in the Central Provinces will also be grown so as to ascertain the effect of environment on quality and yield.

The work on grape vines consists in collecting varieties, growing them and selecting promising ones for multiplication and distribution. The collection already includes 125 varieties.

SCHEME FOR SAN JOSE SCALE (ASPIDIOTUS PERNICIOSUS).

Survey in the Punjab and North-West Frontier Province.

So far as is known the San Jose scale first came into India on infested nursery stock imported into Kashmir from Europe in 1913. It is also suspected to occur in Afghanistan. There being as extensive fruit trade from Kashmir and Kabul to northern India, and no quarantine regulations on overland routes, the pest has spread considerably and is now found in various parts of the Punjab and the

North-West Frontier Province. Fortunately it is yet at a stage where it can be dealt with, though if it is allowed to remain uncontrolled much longer, it may become very serious : it is one of the worst fruit pests known. A survey has therefore been arranged to ascertain the distribution and intensity of the infestation, the entomological work being done at Lyallpur. As soon as the information is available the appropriate action should be promptly taken.

2. Fruit and vegetable preservation.

Grants : Rs. 11,070, spread over 2 years ; application made for a further extension.

In the cultivation of fruit and vegetables for market it invariably happens that quantities of material are unsaleable, either because tney are not quite up to the market standards or because the market is already glutted with other produce. The establishment of a permanent fruit and vegetable growing industry therefore necessitates also the development of methods whereby material in excess of current demand can be preserved.

Fruit preservation can be carried out in two ways ; as a factory industry on the large scale, and as a cottage industry. The factory industry is the only way of successfully handling large quantities of material and catering for the wholesale trade. It depends, however, on two essential conditions :

(*i*) The produce must be of uniform quality so that the purchaser of a tin or bottle of a particular brand may know exactly what it will taste like. Standardisation of quality is essential to a successful wholesale trade and the quality must be sufficiently good.

(*ii*) Fruit preservation on the factory scale cannot be regarded solely as a means of dealing with unwanted produce. No factory can run unless it has full supplies to keep the machinery and the work people fully occupied during the normal hours of employment. Spasmodic activity would be fatal.

Regular supplies must be forthcoming of the kind of material needed, which, however, is not necessarily the same as the material demanded by the fresh market. A preserving factory can, in addition to its normal activities, deal with an excess of produce, such as would arise in time of glut, but this can be incidental only, and not its main purpose.

When the technical difficulties are overcome and the supplies of fruit assured there will still remain important economic and administrative problems such as the relation of the new industry to the protected sugar and tin plate industries.

The cottage industry, on the other hand, is necessarily discontinuous in its operation, and can confine itself to any excess of material not wanted for immediate use or for sale.

The products, however, are hardly likely to find any important place in the market because of their inevitable variation.

At present the work is concerned mainly with factory products : tomato ketchup, citrus squashes, cordials made from culled fruit, and canned fruit of good quality made in regions where transport is difficult, as in the Kulu valley. The biochemical examinations are made by Mr. Girdhari Lal ; they serve a useful purpose in standardisation of the various products, but there is no point in attempting detailed investigations into the biochemistry of fruit. There is a certain similarity between the work here and some of the work done in Professor Ray's Laboratory at Lahore and it would be advisable to link them up.

Attention should be concentrated on the citrus and tomato products until these have reached a standard when they can be put on the market and the industry started.

The best way of ascertaining when this stage has been reached is to submit products to some of the large wholesale firms having expert knowledge of market requirements and to ask for their candid comments : *e.g.*, Messrs. Lyons for good standard qualities, and Messrs. Fortnum & Mason, if superfine qualities are deemed possible.

This could be done forthwith. When the small scale products are passed by the wholesale experts there still remains the very considerable difficulty of establishing the industry on the large scale. This involves an entirely new set of problems which cannot be investigated till the industry is started.

3. Oil Seed Research Scheme.

This work is being carried out by Khan Sahib Choudhury Ali Mohammed, and the grant is Rs. 36,070 spread over a period of 5 years.

The programme is on the same general lines as in the Central Provinces, but it is confined to the Brassica oil seeds of which the Punjab provides no less than one-third of the total Indian production. Three groups are important :

Sarson (*Brassica campestris,* var. *Sarson*) ;

Rape or Toria (*Brassica napus*, var. *dichotoma*) ; and

Mustard or Rai (*Brassica juncea*) ;

all are rabi crops sown in September or October and harvested in March or later.

Within these main groups however, there is a large and very confusing number of varieties or strains, the classification of which is one of the most difficult plant problems in India. It seems improbable that much advance can be made until more is known about the cytology and genetics of the crop. It would be an advantage to have the aid of a cytologist in this investigation.

The different varieties differ considerably in productiveness.

In the meantime, however, some improvement has been effected by purely empirical means. Mass selection is stated to have given strains yielding 1 to 2 maunds more seed per acre, containing 3 to 4 per cent. more oil than the crop commonly raised from unselected seed ; further, the selected seed matures more uniformly and gives a

purer product. It is, however, difficult to maintain stocks in a pure condition owing to the circumstance that most of the varieties are usually self-sterile and are extensively cross-pollinated by insects in the field. The new varieties obtained by mass selection readily degenerate when sown in the field.

It has already been possible to obtain some self-fertile forms and these are being further studied.

Field experiments are made to ascertain the effect of manurial and cultivation treatments on the yield and quality of the oil in various crops.

Somewhat similar work is being done at Cawnpore, and it is desirable that the investigators should keep in touch with each other and also with the Central Institute at Delhi.

Tobacco Scheme.

(Co-operative scheme on flue curing.)

A grant of Rs. 2,500 was given for the construction of two flue curing barns, one at Lyallpur and the other at Jullundur. These are actually outside the zone in which good tobacco is produced but they are needed to complete the main scheme of tobacco research.

The College Departments.

Several of the Departments of the College are carrying out investigations that are closely related to the Council's schemes.

Botanical Section.—Rai Sahib Jai Chand Luthra and his staff have investigated various plant diseases. Some specially interesting work on gram blight has been done by J. C. Luthra, A. Satta and Kishan Singh Bedi.

Mr. Dastur is working on the so-called "Failure" of Punjab cotton, apparently a physiological disease, which, however, is outside my purview.

Cereal Section.—(Ram Dhan Singh). Wheat breeding in the Punjab is greatly facilitated by the circumstance that two crops can be raised in twelve months. Seed harvesting in May in the Lyallpur district can be sent to Lahaul in the mountains about Julu, where it can be sown forthwith and harvested in September or October. It can then be returned to Lyallpur just in time for the autumn sowing in October. Some good varieties of wheat, *e.g.*, C. 591 and of barley have been produced here.

Oil Seed Section.—(K. S. Ali Mohammed). In addition to the Brassica group already mentioned other seeds are also studied: Sesamum, Castor, ground nut and soya bean.

Chemical Section.—(Dr. P. E. Lander). The work is divided into two main groups: soils and animal nutrition.

The soil work includes studies of the reclamation of Kallar or alkali soils. Gypsum, sulphur, farmyard manure and green manure

were all effective, but molasses was not. Where much calcium carbonate is present the method suggested is to grow rice during the kharif and berseem during the rabi season, then to plough this in as green manure.

Soil surveys have been made in connection with various irrigation projects : the soil is classified into cultivable, reclaimable and bad. Surveys are also made of various tube well irrigation regions. The animal nutrition work consists in studying the nutritive value of different local crops ; a special feature is the determination of digestibility which has not previously been done in India.

Sampling of Sugarcane.—A statistical study has been made of the best methods of sampling sugarcane for chemical analysis.

The proposals should be critically examined at Delhi and at the other sugarcane stations with a view to arriving at methods that can be universally accepted.

Utilisation of Molasses.—Both feeding and manurial values were tested. A ration of 5 to 6 lb. of molasses fed daily to heifers and bullocks depressed the digestibility of protein and so resulted in loss of food constituents ; 1-2 lb. daily, however, could be safely used and had no harmful effect.

The experiments on the use of molasses as fertilizer gave negative results. There was no evidence of nitrogen fixation and the results claimed by Dr. Dhar could not be obtained. On the other hand, it appears that molasses could be used as fuel, if the price is less than 8 annas per maund (see page 109).

Potato Dormancy.—Reference has been made to the fact that potato seed freshly lifted from the ground cannot be planted immediately, but requires a rest of several weeks before it will sprout. This problem is of great importance in the hill districts where potatoes are grown. Experiments on the influence of various vapours and gases in shortening this period of dormancy were begun, but they had to be suspended.

Vegetable Rennet.—A large section of the population in India are debarred on religious grounds from eating ordinary cheese made by the use of rennet prepared from the stomach of calves.

It has long been known that the ripe berries of *withania coagulans*, a small herb common in the Punjab, Sind and the North-west, contains a vegetable rennet by which milk can be as satisfactorily curdled as by animal rennet. The active enzyme was isolated in a form so active that one part coagulated 25,000 parts of milk in 40 minutes. It could, therefore, be used in cheese making should this industry ever be developed in India.

Bacteriological Section.—(Dr. S. V. Desai).

The transformations of Nitrogen compounds in the Punjab soils are studied : the effects of molasses and farmyard manure also bacteriological diseases of plant ; and the nodule organisms.

Entomological Section.—(K. B. Mohammed Afzal Husain).

In addition to the advisory work two larger investigations are carried out : one on pink and spotted Boll worms of cotton, flaxseed

by the Indian Central Cotton Committee ; the other on Locusts which is part of the Locust Scheme of the Imperial Council of Agricultural Research (see page 141). Two experimental bee farms are supervised in the hills, one at Nigrota (District Kangra) ; the other at Kulu.

Engineering.—(S. M. Ilahi).

Investigations are made on the design of strainers and the equipment of tube wells.

The farm.—(Labh Singh). The experiments deal with green manuring, here found to be effective ; with fertilizers, of which nitrogenous alone are usually beneficial ; with rotations and cultivation. Improved implements effected considerable saving of man and bullock labour and gave better yields than the cultivators obtained, though not better than could be got if the best use were made of the old implements.

Sugarcane Research : Risalewala.

This farm of 1,100 acres lies just outside Lyallpur.

The rainfall is very low, about 8 or 9 inches a year(1).

The work consists largely in the testing of new seedling canes from Coimbatore or elsewhere, the conditions being unsuitable for the seeding of cane. Resistance to frost can be studied, as frosts are liable to occur in January.

Manurial and cultivation experiments are made. In the first year manures produced no effect ; in the second year, however nitrogenous manure increased the yield ; toria cake proved better than sulphate of ammonia besides being cheaper. There was no advantage in planting in trenches, a method commonly adopted in many parts of India.

Insect and fungus disease are watched and studied with a view to prevention or control. Studies are made of Gur production.

Water Supply to Crops.

Water Requirement of Crops in Lyallpur.

GRANT : Rs. 1,73,970, spread over 5 years.

This work is to be carried out at the Risalewala Farm. Its purpose is to study the influence of varying water supply on the yield of crops : comparing varying numbers of irrigations of the same depth ; frequent light irrigations with heavy irrigations at longer intervals supplying the same total quantity of water ; the effect of tillage ; and the value of "kiaries" of different sizes and shapes in saving water. The results will be applied to suit Zemindary's conditions and practices.

This investigation should be put in hand and such subsequent adjustment should be made as would be required to fit into the larger

(1) At the Jullundur farm the rainfall is much higher but much of it comes in August.

investigation on irrigation, should this be undertaken. The investigation should be extended to include schemes of cropping which would be studied with the purpose of making the most economical use of labour and water, so as to avoid the clashing of peak periods of demand.

The Lahore Institute.

Punjab Irrigation Research Institute(1), *Lahore.*

(Visited February 5th & 6th, 1937.)

Although this Institute deals only in part with agricultural problems and is not financed by a Council grant, the work is so important, both in itself and for its bearing on the question of an all-India Irrigation Research Scheme, that I must refer to it in some detail. The Director is Dr. E. McKenzie Taylor, and he is aided by a competent staff.

The Institute being set up to serve the Irrigation Department much of its work is concerned with engineering problems and lies outside my province. Considerable attention is given in the Physics and Hydraulics Sections, under V. I. Vaidhianathan and Dr. Uppal respectively, to the designs of weirs, dams, river training works, etc., with the purpose of avoiding undermining and counteracting uplift pressures. Large scale models have been designed which accurately represent and reproduce the conditions in practice.

The work that touches most closely on agriculture is that concerned with the movements of the subsoil water and its effects on the soil. Thanks to the foresight of Sir Thomas Higham, annual readings of the spring level of the subsoil water were begun in 1891 and have been continued ever since, while a network, of rain gauge stations has been in operation for an even longer period.

The relation of the annual rise of the water table to the rainfall and irrigation water is studied by the Statistical Officer, Jai Krishan Malhotra. In some areas where annual rainfall exceeds 10 inches it accounts for some 80 to 90 per cent. of the variations of water level in July, August and September. Waterlogging in these areas when it occurs must be remedied by drainage of storm water. A similar result was obtained by Professor Mahalanobis at Calcutta for the areas he investigated (page 156).

The trouble is aggravated by the greater absorption of rain due to the making of bunds, and the blocking of drainage resulting from the construction of roads, railways and canals and the looser condition of the soil due to cultural operations.

Elsewhere, however, the waterlogging is due to seepage either of irrigation water from the cultivators' fields, or from the bed of the canal : it arises because the water cannot get away. A highly interesting piece of work has been done on this subject. The great plain of the Punjab is made up of sand and silt brought down by rivers and filling a basin of much older rocks : the water easily soaks

(1) A full account of the work is given in Report of the Punjab Irrigation Institute, 1936. (Director—E. McKenzie Taylor.)

through the sand and silt but it cannot penetrate the rock so it simply accumulates. The soil surface is fairly level, but the floor of the basin is not : a continuous ridge runs underground across the doabs and acts as a weir holding up the underground water on its upstream side. In general it is only on this side that waterlogging occurs : down stream of the ridge there is a sudden drop in the water table. An important exception occurs at Lyallpur : the water level is here rising in spite of the fact that it lies on the downstream side. This is being investigated ; it may be caused by seepage from the canal, and the remedy is then staunching of the canal ; or by storm water above the ridge producing a kind of cascade effect, in which case the remedy is drainage of the upstream area ; or it may be due to the transmission of the pressure from the upstream to the downstream side of the ridge. The ridge continues through the United Provinces, but here it runs parallel with the rivers and not across them : irrigation has not caused a rise in the water table. It is of course out of question to survey the depth of the sand and silt by boring through it to the bottom of the basin : fortunately geophysical methods can be used for finding the variations in depth. Dr. N. K. Bose, using a Torsion Balance, has constructed a gravity contour map of the rock bed of part of the area, and Dr. McKenzie Taylor is hoping to obtain the use of the more elaborate apparatus for determining a few absolute values so that the rock contour depths can be calculated. The maps thus constructed show very clearly the areas where waterlogging is liable to occur, and the expectation is borne out in practice.

The fate of the water in the canals is also studied. Barely one-half of the water delivered at the head of the canal reaches the field(1), and even this is not all used well. In the rabi season probably no water is wasted, but at the beginning of the kharif season when river supplies are high there is some waste, either in irrigating land that is not subsequently sown, but more frequently in over irrigating fodder crops due to the fear that supplies will be reduced if all the water is not taken.

An interesting investigation, also recalling the work in Professor Mahalanobis' laboratory, is the study of the effect of changes in water level on the life of the village. The histories of the plots are obtained from the revenue records : the changes in water level in areas irrigated, in total revenue, and in human and cattle population will be studied.

No investigations of the optimum amounts and times of application of water to the different crops are carried out here, though experiments have been made by the Chief Engineer, Mr. Woods. The subject is extremely important : data are being accumulated at various centres in regard to rice and sugar cane, but some effective co-ordinating agency is needed.

(1) The estimate is by Mr. Woods, the details being :—

17 per cent. in main lines and branches.

11 per cent. in distributaries.

25 per cent. in the cultivators' water courses.

The loss by seepage is not only a waste of valuable water : it leads to a waste of land by waterlogging and still worse by salt damage. Experiments indicate that in certain specified cases, fortunately of common occurrence, seepage can be greatly reduced by treating the bed of the canal with sodium carbonate : the details have been worked out and as the cost is not high the method is now being tested in the Punjab and in Sind.

The rise in the water table is closely associated with the appearance of salt or "*Thur*". When the water comes to within about 18 feet of the surface any salts present in the soil or the water may begin to appear at the surface. During the winter (November to April) they form a white incrustation which shows up very clearly : from April onwards the incrustation disappears, perhaps being blown away by the dust storms of the spring, and it does not reform. During the summer a dry crust is formed and the salts remain below it : apparently the rate of evaporation from the surface is greater than the rate of capillary movement. The monsoon rains temporarily clear the land of salt. In October or November, however, the salt reappears : presumably in the lower temperature and high humidity of the autumn the rate of evaporation falls below the rate at which the salts are brought to the surface.

In the Chemical Department Dr. A. N. Puri, beside his work on methods of soil analysis (page 131), has made some interesting observations on the formation of the nodules of calcium carbonate which occur at varying depths below the surface of alkaline soils, *i.e.*, soils in which the clay contains sodium as one of its bases. Evidence is adduced that the calcium bicarbonate in the water moving underground reacts with the sodium clay forming calcium clay and depositing calcium carbonate, thus regenerating the layer in which the reaction is proceeding. Sodium carbonate is also formed and travels upwards, increasing the alkalinity of the surface layer, decreasing its permeability and intensifying the deterioration generally. The *change proceeds from below and moves upwards.*

An interesting experiment in reclamation by electrodialysis is being tried.

I have devoted considerable attention to this work because it is among the best I saw in India and it has important bearings on my proposal for an all-India Irrigation Research Station.

The farm at Chakanwali.

For some years Dr. McKenzie Taylor had an experimental farm at Chakanwali where he investigated the effects of salt on growing crops and sought for methods of removing it and reclaiming salt-ruined soil : this section is under Mr. M. L. Mehta. Unfortunately the work was stopped and so a good opportunity for solving some difficult soil problems was lost. Some useful results, however, have already emerged. Soils with pH of less than 8.5 and a salt content of less than 0.15 per cent. will grow the ordinary crops. When, however, these values are exceeded wheat suffers. So long as the pH remains below 9.5 additional salts can be economically removed : especially sodium chloride and sulphate,

which are removed by simple leaching and the growth of rice which takes up salt from the soil and reduces its alkalinity. If the yields of rice are 20 maunds per acre Senji or other leguminous crop is grown and ploughed in as green manure so as to improve the nitrogen supply to the soil. Reclamation is now complete and cotton, wheat or sugar cane can be successfully grown. Reclamation is slower when sodium carbonate is present, several crops of rice being required to clear the soil so that four or five years elapse before any profit is obtained.

If the pH is above 9.5 no known method of reclamation is profitable : though where money is no object, treatment with sulphur, gypsum, etc., may be successful as in the United States. Usually the three sodium salts are the only ones present in the Punjab. In Sind calcium chloride also occurs and this facilitates reclamation.

Reclamation of land spoiled by salt.

Land Reclamation is not a suitable enterprise for a small cultivator still less for a non-resident Zemindar. The Government might well, however, consider the advisability of letting out derelict land on long leases at peppercorn rents and favourable water terms to large farming syndicates or active cultivators of known efficiency. By keeping the land in cultivation, food and occupation are found for the villagers, the danger of malaria is reduced, and the adjacent land is protected.

Prevention, however, is better than cure. Dr. McKenzie Taylor emphasises the need of making a proper survey before an irrigation scheme is started or extended. The important factors to determine are the salt content and pH values of the various layers of the soil profile, and the composition and depth of the subsoil water.

Dr. McKenzie Taylor's observation that the salts are washed down in the monsoon and come back again in the autumn suggests that the present practice of giving irrigation water only in summer to soils liable to salt is unsound. If sufficient water could be supplied in winter to allow of more rabi cropping he considers that the salt would remain below the surface.

Where the problem is more serious it is necessary to change the system of agriculture and grow salt resistant crops. Rice is the commonest, but after the quantity of salt is sufficiently reduced berseem, lucerne, and sugar beet are also possible where the climate is suitable ; the two former would fit in with dairying and the latter would be useful in a sugar cane area for enabling the factories to extend their working season.

Unfortunately there is no means of knowing with certainty whether the salt trouble is spreading or not, though the indications are that it is getting worse. No soils surveys were made when the irrigation scheme started and such old records as exist are faulty. The records of field cropping taken each season by the patwaris are periodically destroyed ; in an irrigated region they should be kept. A survey is urgently needed. Preliminary observations

suggest that an aerial photographic survey from an aeroplane would enable a suitable ground map to be drawn, on the basis of which a salt survey could be easily made. The problem is so important that I suggest the Council should arrange for an experimental survey to test the value of this method.

Microflora of Alkaline Soils in the Punjab.

GRANT proposed : Rs. 13,120 spread over 3 years.

Certain soil micro-organisms are very sensitive to the reaction and salt content of the soil and do not grow if either exceed a certain limit. An alkali soil unsuited to crop production is equally unsuited for their growth ; the micro-organic flora is therefore very restricted. As the process of reclamation continues and the conditions of the soil more nearly approach the normal, so the micro-organisms are better able to develop, and the flora becomes more mixed. Finally, when reclamation is complete, the flora attains its normal complexity.

Micro-organisms multiply very rapidly, and adjust themselves very quickly to changes in conditions in the soil.

In western laboratories methods have been designed for following the changes in the microflora and these are readily applied to discovering what stage the reclamation has reached. Vegetation experiments need to be carried out simultaneously so that the reaction of the crop to the stages in the reclamation can be correlated with the reaction of the microflora. Usually in Western countries plant growth can take place satisfactorily when reclamation has gone far enough to permit nitrifying organisms to develop. The method has worked satisfactorily elsewhere and there is no *reason why it should fail in India ; it has not proved as useful as* chemical methods and so is not widely adopted.

In this investigation the field experiments were to have been carried out at Chakanwali farm and the bacteriological work at the Lyallpur Agricultural College.

A similar scheme has been put forward for studying the microflora of Kalar soils in Sind.

I am not prepared to recommend either scheme for adoption at the present time. If, however, a Central Irrigation Institute be started and microbiological tests should be desired as part of a larger investigation then the matter could be reconsidered.

The Puri Physico-Chemical Methods of Soil Examination.

GRANT : Rs. 5,250.

A large number of methods of soil analyses have at different *times been devised and the International Society of Soil Science,* after extensive trials by selected experts, has recommended certain of them for general adoption. Wherever possible it is advisable for Indian workers to use these methods : apart from the fact that they have been carefully and critically tested, it is only when they are used that the results can be compared with those obtained in other countries, or studied by other soil workers.

So long as the International methods are adopted for all final and important tests intended for publication there is no reason against other methods for preliminary or local tests provided they give satisfactory results, and that all Indian soil workers will agree to use them.

Dr. Puri has devised a number of methods and given reasons for preferring them to the standard methods. The next stage is for the Indian soil workers to try them, and to decide for what purposes they should be adopted, but always recognising the necessity for using the International methods in investigations likely to be of general interest. The Council has taken steps to refer the matter to the Provinces but so far only Madras and Sind have examined the methods in detail.

Dry Farming.

Rohtak Dry farming. Associated with the Lyallpur Agricultural College.

(Visited February 1st, 1937.)

While a large area in the Punjab is secured against famine by irrigation from perennial canals or from wells, a still greater area is not. In parts of the south-east failure of the harvest is a common occurrence and the provision of famine works has become an almost annual necessity.

Five districts in the south-east, Hissar, Rohtak, Gurgaon, Karnal and Ambala have between them 6.7 million acres of crops of which 5.4 millions are grown by rainfall. A dry farming research farm has therefore been established at Rohtak.

Rohtak is situated in the south of the Punjab about 40 miles north-west of Delhi in a dry region where irrigation is usually impracticable by reason of the depth of the water table and the salinity of the water ; dry farming methods are therefore essential. The rainfall averages about 20 inches, falling mostly in July, August and September, but it is very variable. Rohtak itself, however, has the advantage that canal water is available if necessary.

The chief crop is bajra, sown as a kharif crop in July.

The work falls under three headings :

(1) Soil Physics, done by Mr. Sukhdayal under the direction of Dr. Lander.

(2) Plant Physiology, by Mr. J. M. Rao, working under Rai Sahib Jai Chand Luthra.

(3) Agronomy, done by Mr. L. Tehl Ram.

The Station is new and a soil survey is being made by the Soil Physicist, profiles down to a depth of 10 feet being examined. Both light and heavy soils occur on the farm and the heavy soil is alkaline at the lower depths.

The routine soil work consists in measuring the penetration of rain water on cropped and fallow land and the loss by evaporation under different conditions.

Large numbers of estimation of moisture, nitrate, etc., are made ; at present it is not possible to determine the sampling error and I recommend that the procedure should be modified so that this could be done.

The soil work has the merit that it is closely associated with the field operations. It is done on the farm and is not confined to the laboratory : the effects of the cultivation processes and of the growing crops on the moisture content of the soil can be estimated.

The physiological work has only recently been started. It consists in the study of the water requirements of the various crop plants grown in pots, and of the root system under different conditions of growth.

The water requirements in pot experiments have been determined elsewhere and there seems little advantage in multiplying these particular measurements. The field experiments, however, should be developed. Certain parts of the farm are underlain by a layer of soil 6 to 8 inches below the surface in which roots are liable to rot. Preliminary observations suggest that those varieties grow best which have a good horizontal root system above this layer and a tap root strong enough to penetrate and get through to the depth below.

The agricultural work consists in finding the effects of deep and shallow cultivation on the absorption of rain water ; on the effect of surface cultivation after showers of rain ; on inter-culture of crops ; the value of bunds in conserving rain water ; effects of varying the seed rate, and of farmyard manure and different rotations on soil moisture and crop yield.

Rohtak is a long way from the Central Indian group of four stations, but the Council has arranged that the staffs of all five stations concerned with dry farming should meet periodically for discussion of their work.

Grass land experiments.

Phosphatic Manuring of Grass Land under low rainfall.

Under moderate and high rainfall in temperate climates it is well known that phosphatic fertilizers greatly improve the feeding quality of grassland. An experiment was carried out at the Government Cattle Farm at Hissar to discover if similar results could be obtained in dry conditions. The rainfall averages 14 inches, but is very irregular, both in amount and distribution.

It is very desirable that more experiments on this subject should be made : in Australia strikingly good results are sometimes obtained in equally dry conditions.

Mineral Contents of Fodders and Feeding Stuffs.

Officers in various Provinces and States in India make numerous analyses of fodders and feeding stuffs, paying special attention to the mineral substances present.

Dr. Lander has emphasised the necessity for adopting uniform notations and methods. I agree that this is essential. Unless uniform methods are adopted by different analysts, there is considerable confusion and the results may be very misleading. Dr. Lander's suggestions should be carefully examined and a memorandum should be drawn up at an early date setting out prescribed methods that must be adopted in all schemes financed by the Council, though leaving the individual workers free to adopt others also if they wish to do so.

The Punjab University, Lahore.

(Visited February 4th, 1937.)

Investigations bearing on the work of the Council are proceeding in several of the Departments of the University.

Botanical Department. Wither tip of Citrus Trees.—Grants totalling Rs. 13,800 were given by the Council in aid of Dr. H. C. Chaudhuri's experiments on the wither tip of Citrus trees, a disease caused by the fungus, *Colletotrichum gloeosporioides*, which besides, causing the tip to wither, also causes a great loss by the dropping of immature fruits. A spraying treatment was devised which, it is said, has now become almost universal in the Province as a means of effecting control.

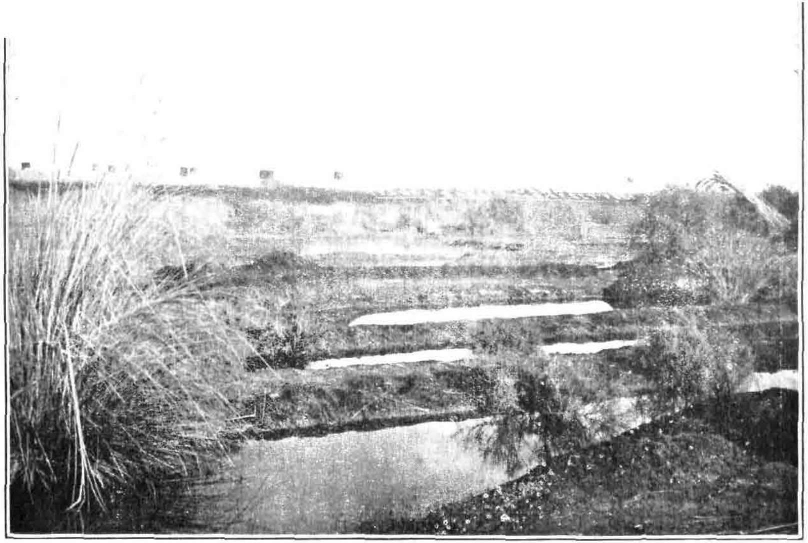
Organic Chemistry Department.—This is under Professor J. N. Ray, who had studied organic chemistry under Professor Robinson of Oxford, and therefore became interested in the organic constituents of plants. Several of the investigations going on here are related to the Council's work, especially those on dry plants, on fruit juices, and on insecticidal plants. I recommend that the Biochemist for the fruit preservation scheme at Lahore and the chemist in charge of the plant insecticide investigation at the Agricultural Department laboratories, Bangalore, should both spend some time here to learn what they can from Professor Ray.

Physical Chemical Department.—Professor S. S. Bhatnagar is well known for his investigations on electro-chemistry and electromagnetism, and numerous studies on these lines are in hand in his Department : unfortunately I could think of no way of linking them up with agriculture. He has, however, had charge of two of the Council's schemes.

(1) The effect of ions on the growth of plants. (Amount of grant, Rs. 6,523.)

The effects of salts of various heavy metals : uranium, thorium, cerium, copper, manganese and zinc have been studied in water, sand and soil cultures ; the observations, however, being confined to measurements of plant height and of dry matter finally formed.

The work is now concluded. In similar work elsewhere it has been found that the chief interest lies in the physiological and pathological consequences of supplying or withholding these various metallic ions, and if the subject is reopened it should be done in conjunction with a plant physiologist or pathologist. Many investigators have shown that small quantities of certain elements are essential to healthy growth and in their absence plants suffer from certain physiological diseases. Sometimes these diseases occur in the field



Sind : Waterlogging difficulties.

and in that case small additions of the missing element have remarkable effects in restoring the health and full growth of the plant.

(2) *Another investigation which received a grant of Rs. 4,150* spread over 2 years consisted in studying certain soil properties with a view to explaining the field behaviour. The water extract, hydrochloric acid extract, total nitrogen and pH values were determined for a large number of soils, but no relation with fertility was found. It was recognised that there were variations in climate, in water supply and in seed.

The problem of explaining soil fertility on chemical and physical grounds is extremely difficult, because of the profound effect of water supply and of climate, and if any future investigation on the subject is started, it should from the outset be associated with an elaborate system of carefully planned field experiments. The work, would, however, be costly and troublesome and I doubt very much whether it would be worth the expense.

SIND.

Irrigation in Sind.

(Visited November 26th, 1936.)

The great irrigation schemes in Sind are served by a competent group of engineers, by an Irrigation Research organisation at Karachi, and by an agricultural experimental station at Sakrand (Nawabshah district) on the left bank of the Indus. It is proposed to establish an *experimental farm on the right bank at Dokri.* The problems fall into two groups associated respectively with the safe delivery of the water and with its optimum ultilization. The Irrigation Department is concerned with the first of these : the problems include the avoidance of loss by seepage from the canals, with consequent waterlogging of adjacent land whereby both farms and villages may be spoiled.[1] As part of the programme, detailed records are kept of the fluctuations of water level in a number of observation wells so that the changes in water profile can be followed. The Agricultural *Department undertakes experiments on the utilization of the water.*

The agricultural problems.

The opening of the Lloyd Barrage in 1932 has had some striking effects on the agriculture of Sind. The area under fodder crops has much increased : the acreages of wheat and cotton have more than doubled, and, even more important, while formerly the cotton was all short staple, now much of it is medium staple cotton of good quality. Even more of these medium stapled cottons could be grown if varieties more resistant to jassid and white fly were available. Search for these is steadily proceeding.

On the other hand the area under the grain crops has not increased, in spite of the increased population ; indeed it is stated that both yield and quality of juar and bajri have fallen : the production of oil seeds has also decreased.

---

(1) A Report on Waterlogging in the Khairpur State, through which the Rohri canal passes, has been made by Sir Bernard Darley and Mr. Waller.

The areas under the various crops and the estimated quantities produced are given in Table 1.

TABLE 1.—*Cropping in Sind before and after the setting up of the Lloyd Barrage in 1932.*

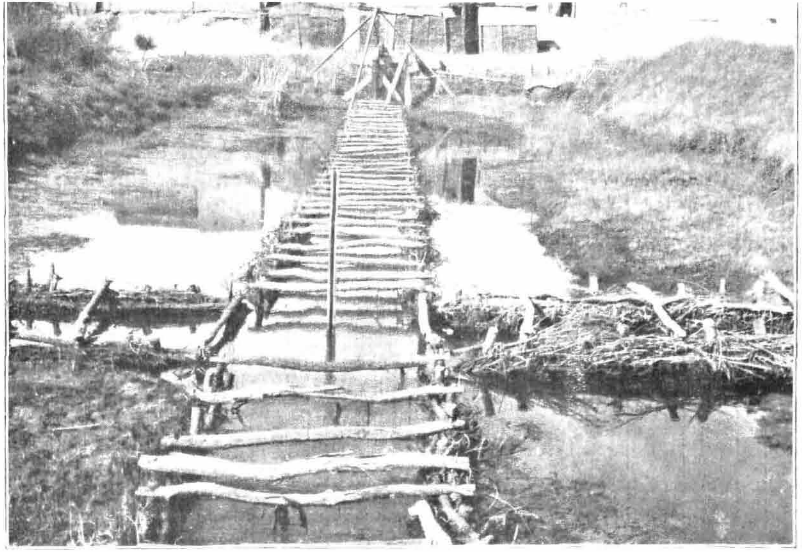
Crop.	Acreage in thousands.			Production Tons in thousands.		
	1913-14-1917-18.	1923-24-1927-28.	1933-34-1935-36.	1913-14-1917-18.	1923-24 1927-28.	1933-34-1935-36.
Cotton	264	339	649	..	..	..
Wheat	594	441	1,157	237	93	278
Rice	1,166	1,148	1,097	399	455	403
Jaur*	617	549	466	187	118	103
Bajri†	979	1,064	854	164	150	99
All grain crops except wheat	3,188	3,276	2,921	814	807	669
Fruit and Vegetables‡ ..	44	46	49	..	..	..
Oil Seeds	404	299	194	..	..	..
All crops	4,609	4,554	5,141	..	..	..

* Chiefly in Upper Sind.
† Chiefly in middle and lower Sind.
‡ Two years only 1933-34-1934-35.

According to the original plan the 1933-34 area under wheat should have been 1.01 million acres and under cotton 415,000 acres : both figures were in fact somewhat exceeded.(1) The ultimate area is planned to be 2 million acres under wheat and 800,000 acres under cotton. The cotton acreage may readily be attained : the wheat presents more difficulties, partly technical, partly economical. Most of the wheat is sold out of the province, either to other parts of India or to overseas markets. In either case uniformity of quality is essential for obtaining the best prices ; the Department has recognised the need for this and is endeavouring to replace the present mixed crop by improved selections from the local varieties or by strong, rust resistant Pusa wheats.

At present prices the cultivation of wheat is evidently profitable especially in Upper Sind where the relatively long winters are favourable to the crop and the present improved varieties are sufficiently rust resistant. In middle and especially in lower Sind the winters are shorter, and the milder and more humid conditions are less favourable to wheat ; present varieties are not sufficiently rust resistant. It is not easy to say what would happen if the original plan were fulfilled and another million acres of wheat were grown in Sind. The cheapest form of cultivation is presumably the " bosi ", *i.e.*, where water is given before sowing only, and not afterwards—or what amounts to the same thing, where the wheat is sown on the banks of the Indus as the flood recedes. But this area does not increase : it remains roughly at about 200,000 acres : the increase is

(1) W. J. Jenkins, Crop Planning Committee Conference, 1935, p. 48.



Sind : drainage difficulties owing to sand particles.

in the ordinarily irrigated area. How much further can this go ? Can the two million acres of wheat be ultimately achieved ?

The answer to this question turns on the extent to which wheat and cotton can be successfully combined in one system. It is not a usual combination : indeed only in lower Egypt can it be found outside of India, and only in the Punjab and to a less extent the United Provinces is it common in India. The southern limit of the wheat belt and the northern limit of the cotton belt overlap only in a relatively narrow zone. The difficulties are on the practical side.

The two crops clash both at sowing and at picking time. The staple cotton must be sown between mid-March and mid-May, just the period when the cultivator wants to thresh his wheat : the cotton needs aboundant water in October, when water ought to be put on the wheat land to allow it to be cultivated ; finally, cotton picking is in full swing from September to December, when the wheat ought to be sown. Desi cotton can be sown later-up to mid-June, so as to avoid the clash with threshing, but it flowers and bolls at the same time as the staple cotton, hence the other difficulties still remain. The trouble is intensified by the scarcity of population in Sind and the constant malaria.

No way of reconciling these conflicting requirements is yet in sight. The cultivator usually tries to avoid the difficulty by sowing the wheat late, often in December or January, but this is rarely profitable.

The Agricultural Department could render valuable help to the cultivator by improving the implements so that work can be done more expeditiously and economically (1) and by developing some useful rotations that would avoid some of the present clashes. The rotation must be designed so as to fit in with the agricultural facts. Wheat is the most desirable rabi crop : it requires less water than any other of the cash crops. (2) and it is always likely to be saleable as, apart

(1) Mr. J. Cumming is doing some useful work in this direction.

(2) Valuable data on this point are contained in the "Statistics of Irrigation Water Distribution and Working of Distributaries of the Canals in the Punjab for the year 1932-33" (Government of the Punjab, Public Works Department, Irrigation Branch, Lahore, 1934), showing how much water was supplied to various crops :—

—	Acres irrigated per cusec. "Duty".	Depth of water supplied in feet. "Δ".	Rainfall during growth ; feet.	Canal.
Kharif crops—				
Rice	78	4·7	3·0	Upper Chenab p. 40.
Cotton	139	2·6	0·3	Lower Chenab p. 46.
Rabi—				
Wheat	232	1·6	..	

from the overseas demand, it is being increasingly consumed in India. Bajri and juar fit in to the agricultural programme more easily than wheat ; they are sown in July and reaped in September, so that they do not clash badly with cotton operations, although they have about the same peak demand for water. Their economic value, however, is less than that of wheat. Oil seeds might be better as cash crops. They were formerly much grown in Sind but their cultivation has decreased considerably since the Barrage scheme developed, the present acreage being only about one-third of what it was. Attempts to increase the area are being made by the Department, the advantage being that, as there are several sorts of oil seeds sown and harvested at different periods, they allow a better spread-over of the work than is possible with wheat. The rabi crops, rape and mustard, have always been the most popular.

At present, however, the marketing arrangements are not good and it might be difficult to improve them.

Fodder crops are probably the best alternatives to wheat. Berseem or Shaftal (Persian clover) broadcasted in the cotton at the end of the picking season, furnish valuable food for livestock besides enriching the soil. Wheat could then follow, making a rotation :—cotton : berseem : wheat :(1) which could be followed, as in parts of the Punjab by the sequence : maize or some pulse crop sown in April, and this by rape sown in October, then back to cotton An intensive rotation of this kind would necessitate manuring. There is already considerable local demand for fodder owing to the large cattle population(2) and so far as can be seen this is capable of marked expansion, for Sind seems to be very suitable for developing a livestock industry : it possesses two of the best and most popular milch breeds in India : Sindhi or red Karachi, and Thar Parkar : good milking cows can be produced for sale to the towns to replace the wastage.

Dairy produce could no doubt be manufactured but the distance from market may cause difficulties in selling. Fruit and vegetables also afford possibilities.

This question of suitable sequence of crops is so important that it should be closely studied in relation to the economy of the holding considered as a unit.

In Sind, more than in most parts of northern India, there is special need for educational and extension work. There is no tradition of good cultivation among the *Haris*. It is not uncommon for them to broadcast the cotton seed, to plough it in and do all the subsequent cultivations by hand, a costly and ineffective method as compared with drilling in rows and intercultivating by bullock-drawn implements. The Punjab colonists are better cultivators than the Sindhis ;

---

(1) Cotton could follow wheat, but wheat could not follow cotton because the cultivator likes to leave the cotton plants standing till the end of February so that after picking is over in December his cattle can eat the stems, leaves and unopened bolls : these are indeed the chief source of food during January and February. After that the animals are given leaves and branches of trees till wheat straw is available in April.

(2) There is a local saying that it takes five cows to keep one Sindhi family.

Sind before irrigation.

many of them are intelligent and good farmers : one recognises the agricultural touch directly one gets on to their land.

Moreover there are in Sind, as in some of the other irrigated areas of Northern India, a certain number of progressive large cultivators both European and Indian who manage their estates very well and who render general service not only by their example but also by multiplying desirable stocks of seed and maintaining good herds of cattle.

The method of individual ownership and cultivation has been adopted in Sind, while in the Gezira (Sudan), perhaps the nearest approach in the Empire to the Sind scheme, the whole region was put under the control of a Syndicate, which runs it as one large farm in a kind of partnership with the Government and the tenants. The Government provides the land and water ; the tenants do the cultivation ; and the Syndicate provides the minor canal system, advances the working capital, seeds, fertilizers, etc. (which the tenant must repay), prescribes the cultivations and treatments, provides ginning and storage facilities, and sells the produce. The proceeds are then divided on an agreed basis : the Government have 35 per cent., the tenant 40 per cent., and the Syndicate 25 per cent. The arrangement works very well, the Syndicate in its own interests has to take good care both of the land and of the tenants ; the system, therefore, combines the economic advantages of large scale production and the social advantages of a settled tenantry. Time will show which of the two methods is the better, but in the event of any further large irrigation development in India it would be advisable to consider the possibility of adopting the Gezira model.

The work of the Sakrand Station.

The Sakrand Station was started in 1925 by Dr. H. H. Mann who rendered great service to the development of Sind agriculture. Dr. Tamhane was in immediate charge from 1930 to 1936 under the general direction of Mr. W. J. Jenkins, the Chief Agricultural Officer for Sind who published an excellent programme of work before he left. (1) The officiating administrator at the time of my visit was Rao Sahib K. I. Thadani.

The Chemical Section is now under Mr. M. A. Shama Iyengar, who, like his predecessor, Mr. Tamhane, is doing some good work.

The chief crops are wheat, juar, bajri, rice and cotton.

The water requirements of crops are studied and also the methods of maintaining soil fertility in view of the heavy cropping plan proposed for the area.

Stress is rightly laid on the value of berseem in maintaining the fertility of the land and providing food for livestock thus facilitating the development of mixed farming, which is regarded as the most suitable for the Barrage areas.

The salt problem is studied in the Chemical Department : properly managed it ought not to give trouble in Sind ; it is much simpler here than in the Punjab, since the dangerous sodium carbonate is

(1) See his interesting " Summary of present position work of the Agricultural Department in Sind, Karachi, 1936 ".

almost absent. The usual salts are sodium chloride and sodium sulphate and the beneficial calcium carbonate and sulphate : the total salt content varies from 0.5 to 6.0 per cent. or more. The irrigation water is very good, containing only 23 parts of salts per 100,000 of which a considerable proportion is calcium salts.

Several methods of reclamation of salt land (" Kalar ") have been tried by the Chemical and Agricultural Departments.(1). So long as the land is not alkaline it can be reclaimed by flooding followed by immediate cropping : a suitable combination is cotton and bajri in equal area in the kharif season and berseem on the same area in the rabi season. Fallowing, on the other hand, tends to bring the salts to the surface, and the cropping system is being arranged to reduce it to a minimum. Indeed one method now under observation consists in leaving the soil to lie fallow and allowing the salts to rise to the surface and concentrate in the top inch of soil which can then be scraped off and removed.

Where the soil is alkaline more drastic methods are needed : prolonged continuous leaching followed by a crop of berseem.

The Botanical Department under Mr. Thadani is concerned with the selection of suitable varieties of crops for the Barrage areas.

The physiological section under Mr. B. M. Dabral (Physiologist) is financed by the Indian Central Cotton Committee, Bombay, and deals exclusively with cotton, which lies outside my province.

The properties desirable in the conditions of the Barrage areas are stated to be a fairly long vegetative period, flowers produced quickly and within a short time, and rapid opening of bolls. The need for water is greatest at the time of flowering and fruiting : in contradistinction to wheat, which grows equally well however the water is distributed, within reason.

The work on oil seeds is financed by the Sir Sassoon David Trust Fund, Bombay.

Citrus, particularly loose-skinned oranges and grape fruit, and vines grow well at Sakrand and attempts are being made to encourage their growth elsewhere. The horticultural officer, Mr. Ulvi, seems to be doing good work.

The Agricultural Department under Mr. M. V. Barakzai aims at collecting the results of the other Departments and applying them in practice.

There is no entomologist though as the work develops it will be necessary to appoint one, and also a plant pathologist. It is courting disaster to have large irrigated tracts under cultivation without keeping close watch on plant diseases and pests.

(1) About 1908 the Bombay Department started a reclamation farm at Daulatpur (Sind) under Mr. G. N. Henderson, who came from the Abukir Company in Egypt, and introduced their methods, which worked satisfactorily. The first step in the reclamation was to level the land, then flood it, and if it was alkaline, to keep it flooded for any period up to 6 months, then to grow berseem. The farm was closed about 1912, its work being regarded as completed.

Mekran : Where the locust breeds and feeds.

Sind has the possibility of great success or of tragic failure depending largely on the quality of the staff selected to look after the irrigation works and to guide the cultivators. In no part of India I visited is it more essential to attract the best men possible for carrying out the soil and crop investigations.

The Locust Scheme.

(*Schistocerca gregaria.*)

(Field work visited December 2nd, 1936 ; laboratory work at Lyallpur visited February 7th, 1937.)

Parts of northern India are periodically devastated by locusts : the last visitation commenced in 1926 and lasted until 1931. It did much damage but it also stimulated research on the subject.

The difficulty of the early workers was that locust swarms had not attracted attention till they became dangerous : the initial swarms which are of chief importance to the investigator were unnoticed or unrecorded. Careful enquiries, however, enabled the great locust invasion of Sind in 1926 to be traced to the Mekran reks : the desert coastal region west of Karachi. Later observations proved that it was in fact part of a world movement involving Persia and Arabia, but also showed that this Mekran district is the source of outbreaks of locusts in India.

The Council started a locust Research Scheme in 1930, under the charge of Khan Bahadur M. Afzal Husain, then Entomologist to the Government of Punjab, stationed at Lyallpur. In his laboratory there he studied various problems connected with the life history and bionomics of the insect ; at the same time a special touring staff was organised under Rao Bahadur Y. Ramchandra Rao for making locust surveys in the desert areas of Baluchistan, Sind and Rajputana, seeking out the areas where the locusts breed and from which the swarms start.

When Mr. Afzal Husain was appointed Principal of the College in April, 1933, the work was split into two parts : the main staff was established at Karachi ; but the laboratory work on bionomics was continued at Lyallpur.

The combination proved a particularly happy one, for no Indian entomologist was better able than Mr. Husain to carry out the laboratory investigations and Mr. Rao has been very successful in his studies of the locust in its natural habitat.

The locust movements in India as traced by Mr. Rao are extraordinarily interesting.

The permanent home of the locusts in India is the Mekran ; they are always to be found there, but ordinarily in relatively small numbers and only in the solitary stage. In order to keep watch on them a Field Research Station was set up in 1931 at Pasni, followed later on by a second Station at Ambagh, and locust observation posts in the deserts of Rajputana and Sind. A central laboratory was established at Karachi from which the desert surveys and the work at the research stations is organised.

The eggs are deposited in the sand and if this is moist enough the first brood appears in March and April as solitaries. If, as often happens, there is no rain, only few survive and the numbers never become great. If, however, heavy rain comes at the time when the March brood is ready to breed, they multiply rapidly, become crowded and are converted into the swarming phase. The physiological basis of this curious change from solitary to swarming phase is not fully understood, but its practical significance is very great. The incipient swarms, however, remain in Baluchistan till June and July, when they fly to Sind, Rajputana and the south-west Punjab districts. There the locusts breed as soon as the monsoon rains provide sufficient moisture : these last from mid-June to October, and when they end, breeding draws to a close ; if the rains are sufficiently heavy, two generations are produced. In the autumn the locusts fly back again to Baluchistan, and the cycle recommences. Sind, therefore, suffers two visitations : one in summer on the way out, one in autumn on the way back. Mr. Rao thinks that this is not a deliberate cyclic movement, but is the result of the different prevailing wind : in summer the wind commonly blows from the south-west and in winter from the north-east. The locusts are not actually carried by the wind, but they cannot fly against it and so it determines their direction.

The continuance of the locust infestation, once it starts, seems to depend on the ability of the locust swarms to transfer from the areas of winter rainfall to those of summer rainfall and *vice versa* at the proper time to allow them to produce two generations in one season.

During October and November the locust remain in the Baluchistan coastal region. If the rainfall is good, they breed again ; the eggs are laid in February and the hoppers are hatched out in April or May. So the cycle continues.

It sometimes happens in seasons of heavy infestation, that some of the swarms, instead of ending in Rajputana, go much further eastwards ; in 1930 they went as far as Bihar and Bengal : then of course there is trouble.

The work in Ambagh consists in studying the habits of the insect in its natural home and observing particularly the effect of food on the length of the hopper stage and in the interval between attaining the adult stage and sex maturation.(1) Certain foods, particularly juar, maize, "Marrand" (*Heliotropium undulatum*), "Kullichk" (*Cyperus arenarius*) much accelerate sex maturation.

Detailed observations of the density of the locust population are made so as to give warning of any sign of marked increase.

The Ambagh station is in charge of Mr. Batra, who succeeds in achieving a large amount of work under very difficult circumstances for life at Ambagh is lonely and very trying ; few men could remain there for long without their work suffering. It is essential that a competent entomologist should be stationed there but all possible efforts should be made to mitigate the solitariness and discomfort.

---

(1) The locust goes through four physiological stages : the egg, the hopper, the sexually immature adult and the sexually mature adult stage.

The work at the other stations is on the same general lines : the conditions for the workers are at least as trying and difficult as at Ambagh.

The central laboratory at Karachi is in charge of Rao Bahadur Y. Ramchandra Rao. There Dr. Mukerji is studying the biometry of the locust, measuring the wing length and femur and calculating the ratio of one to the other, an important figure since it constitutes an index to the phase of the locust, whether solitary or gregarious. At present he has to make the numerous calculations by ordinary arithmetic, but this is very wasteful and I strongly recommend *that a hand-calculating machine be obtained.*

Rao Bahadur Y. Ramchandra Rao has his staff so well organised that he could proceed to experiment on locust control should the occasion arise. Since 1930, however, there has been no swarm of sufficient size to permit of any experimental work, and consequently this part of the investigation remains in abeyance.

The laboratory work at Lyallpur has brought out some very interesting results. The main problem is the study of the effect of temperature on the rate of multiplication. It is shown that several broods can be produced in a season if the temperature is favourable ; the locusts can indeed start egg-laying when only 13 days old if the temperature is high enough, though they do not remain healthy in these conditions. The solitary forms are green and the gregarious black.

This black colour, however, is lost as the temperature rises, and beyond a certain temperature the locust become white.

At the time of my visit there were no experiments in hand because there was no material : if no further invasion occurs, it is proposed to disband the Lyallpur staff.

The question has arisen whether locust watching and control should continue directly under the aegis of the Council or should become a permanent service. I am strongly in favour of the latter course. The locust problem is permanent. Constant watch must be kept and continuous experiments carried out to discover ways whereby incipient swarms can be destroyed before they reach proportions at which they become a menace. It is imperative to avoid *the mistake of closing down locust research when there is no invasion*, for then only have the locust officers the time for doing the necessary careful work.

The service besides being permanent should have its own organisation : *it should not be regarded simply as a part of the Entomological Department.* It should be linked up with the Council through the Standing Locust Committee.

The Baluchistan outbreak area is not restricted to the boundaries of India, it extends into Iran, but no locust investigations are carried on there. The possibilities of extending fithe locust surveys into Iranian territory should be examined so that at any rate warning of impending invasion might be given.

Dr. B. P. Uvarov, with whom I have discussed this question, points out that apart from locally produced swarms, southern

Iran and western India are liable to be invaded by swarms arriving by stages from Arabia and even Africa. A permanent locust service in India would not completely guarantee against future invasions : this could be done only by international preventive control throughout the whole area stretching from the Sudan to India. The question is urgent : Dr. Uvarov informs me that observations on the coastal areas of the Red Sea made during the winter of 1936-7 suggest the possibility of a new outbreak of the Desert locust. It is very important that the Council should get in touch with the Imperial Institute of Entomology and ascertain what steps could be taken to expedite locust control in these lands outside of India.

Karachi is so far as I can judge the best centre for the permanent service and Mr. Rao's success points to him as a suitable officer in charge. In view of the fact that locust trouble, if it comes, will come quickly, I recommend that a certain number of entomologists in northern India should spend some time at Pasni or Ambagh so as to familiarise themselves with the general groundwork of the locust problem. If invasions occurred they could then readily act under the instructions of the Chief Locust Officer.

BALUCHISTAN.

Fruit growing and fruit canning at Quetta.

(Visited November 29th-30th, 1936.)

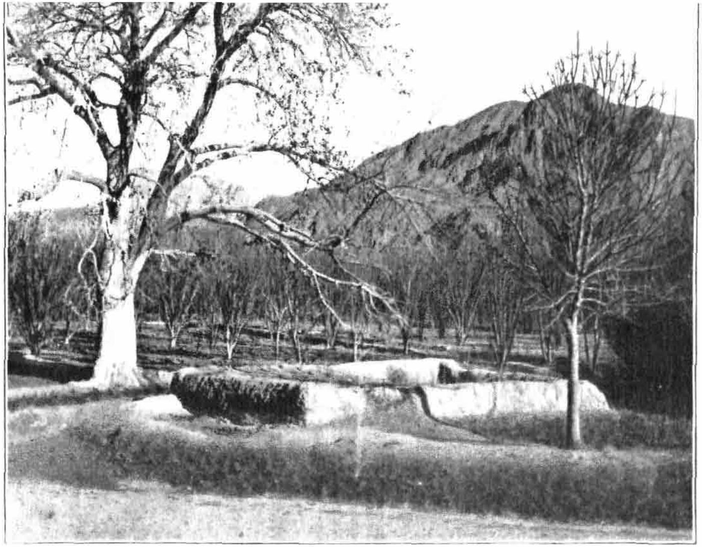
Excellent quality fruits are grown in Baluchistan, particularly in the plain around Quetta ; these include all the English fruits and in addition peaches, apricots and grapes. The demand has grown so much that the acreage under fruit is increasing. An Experimental Fruit Farm was started in 1912 by the Howards at Quetta : it was almost abandoned in 1919 but was revived in 1932 and is now in full swing under Mr. A. M. Mustafa. The staff includes an entomologist and a mycologist who are studying the local pests and diseases. The work is being well done and seems likely to lead to useful results. The Council has given a grant of Rs. 67,000 spread over 5 years.

A fruit canning scheme is shortly to be put in operation, a grant of Rs. 49,600 spread over 5 years having been given for the purpose. I recommend that the officer in charge of this work should spend some time at Lyallpur, where good results have already been obtained, in order that he may thoroughly familiarise himself with the methods of overcoming the numerous difficulties.

NORTH-WEST FRONTIER PROVINCE.

(Visited February 2nd-4th, 1937.)

This province compares favourably with any of the others in India in agricultural utilisation of its available land. Out of its 8½ million acres only about 2½ million are sown, but of these nearly 1 million are irrigated : about 60 per cent. of the sown area is under rabi crops, 40 per cent. under kharif crops. Wheat is the most important crop of the province and occupies nearly a million



Fruit growing in Quetta.

acres : maize comes next with about half a million acres : followed by gram, of which there is about a quarter of a million acres.

While the present record is good the Government is anxious that it should be better.

Two experimental farms have been organised : one at Tarnab near Peshawar and the other at Charsadda about 20 miles away.

Judging by purely physical consideration, there are four directions in which the agriculture of the Province could be developed : general farming ; the breeding of livestock ; the production of seeds ; and the growth of fruit and vegetables. I shall confine myself to the last two.

The production of seeds.

Already the North-West Frontier Province is the most important source of supply of berseem seed, though I heard numerous complaints in other provinces of contamination with weed seeds. This could be remedied by the installation of cleaning machinery and the Department should consider the possibility of issuing certificates for properly cleaned seed. The raising of other seeds also might be tried, including seed potatoes.

Fruit and vegetable culture.

The soil and climatic conditions of parts of the Province are very suitable to the production of fruit and every effort should be made to develop this industry. The deciduous fruit trees familiar in West Europe—pears, plums, peaches (especially No. 6 and Elberta), etc., flourish and fruit of really good quality can be obtained.

Attempts to improve the cultivation of fruit were begun in 1910 and from that time onwards, good commercial varieties have been imported from America, Europe and Japan, and the Zemindars have shown considerable enterprise in planting orchards. I was informed that in the last 17 years over half a million budded plants of these fruit trees have been distributed from the Government Fruit Farm, mainly to the Zemindars of the Peshawar district, and that many new orchards have been laid out. This district and the Kumaon and Kulu valley regions of the Punjab are among the few areas in India where commercial orchards of named varieties of deciduous fruit trees are planted.

The Council has sanctioned a grant to the Experimental Fruit Farm at Tarnab of Rs. 20,000 spread over 5 years for the purpose of experiments on the manuring, irrigation and management of deciduous fruit trees, particularly peach, plum and pear.

In view of the distance from the large cities of India it would be necessary also to develop a fruit and vegetable preserving industry. A beginning has already been made at the Experimental Farm at Tarnab, and this should be further extended. The senior staff, however, should be sent for a refresher course to Lyallpur where considerable progress with these problems has already been made.

A well developed fruit industry would also necessitate as a subsidiary industry the making of containers, both boxes and baskets : there would also be the possibility of honey production.

The growing and preservation of vegetables should also be studied.

Sugar Cane.

Over 40,000 acres of sugar cane are grown in the Province, much of it in the Charsadda division. This district is so far from the other sugar growing districts of India that it needs its own farm where tests can be made to discover which varieties are best suited to the local conditions. Tarnab farm while suitable for cane testing, is too far from the cane growing districts to be of full benefit to the Zemindars ; hence the necessity for a second farm. The Council has therefore made a grant of Rs. 63,750 spread over 5 years, in order that a sugarcane research station may be established in the Charsadda division. The work will consist in making varietal, manurial, cultivation and irrigation tests on the usual lines with the view of overcoming the two chief difficulties of sugarcane cultivation in the Province : the liability to frost in winter, and the comparatively short growing season.

Much of this work is of Provincial rather than all-India importance but two problems of general interest can be studied in this region more easily than in the Punjab or United Provinces : the question of resistance of the different varieties to frost, and windrowing, a method practised with success in Louisiana. Some observations are possible at the Punjab station, Lyallpur and Jullundur, and even at Muzaffarnagar or Shahjahanpur but frost cannot always be relied upon ; here, however, in the North-West Frontier Province it comes with certainty every winter, and systematic tests of frost resistance can therefore be made.

The Province differs from most of the others in India in that its area of sugar cane is not increasing. Apparently the cultivators find some difficulty at present prices of gur, probably due to the losses caused by frost.

Much of the cane standing at the time of my visit in early February, 1937, was frosted, and it seems improbable that supplies of any sufficiently frost resistant variety could be developed in the near future. Assuming that a suitable variety were found or bred, something like seven years must elapse between the production of the new seed and the widespread distribution of the resulting cane : it would be unwise to count on this possibility in planning a general improvement. The tests of new varieties for frost resistance should certainly be continued and the existing cane-growing cultivators should be given all possible help in dealing with their problems.

Colonel E. W. C. Noel, who has worked strenuously for the development of the Province, has suggested that a combination of sugar-beet and sugarcane would overcome the physical difficulty of the frosting of cane, and I am not prepared to dispute this. The difficulty of price still remains, for nowhere, so far as I know, can

sugar beet compare economically with sugar cane : moreover with the rapid expansion of sugar production in India it is hardly possible to forecast future developments.

The Islamia College.

This well known College possesses several scientific departments and a farm of some 200 acres which could be used for experimental purposes. At present it has only a limited supply of water drawn from a private canal, but there is the possibility of tapping the river at a point some 10 miles away or of sinking a tube well to the water table which is probably about 100 ft. down.

It is understood that the College Authorities are prepared to take an active part in the development of the agriculture of the Province if the necessary means were provided, and this possibility should be very sympathetically considered. In view of the circumstance that neither of the experimental farms possesses much in the way of laboratory equipment, it would be an obvious advantage if the laboratory work in connection with the entomological, mycological chemical and analytical problems could be carried out at the College, and I recommend that arrangements to this end be discussed. Among the chemical problems which the College could take up is the claim that the silt brought down by the winter flood has high manurial value. It is difficult to understand why, and the question deserves proper investigation, first to discover if it is true and then to find out the reason.

In regard to the farm, I recommend that representatives of the College and the Government should meet to draw up a simple scheme of field experiments on farming problems of practical significance, including fruit and vegetable production, to be carried out at the College. The frost resistance tests of sugar cane could also be included.

Technical Staff.

Such good progress has been made in the province that the pioneering stage may now be said to have ended and the time seems opportune for the Government to consider the advisability of setting up a technical department with a fully trained staff, on the lines adopted in other Provinces, the Director of which could exercise detailed supervision of the further agricultural developments which the present indications seem to justify.

THE SIMLA EXPERIMENTS.

POTATO BREEDING IN NORTHERN INDIA.

(Visited March 18th, 1937.)

GRANT : Rs. 40,550 spread over 5 years.

Although it does not occupy a large area the potato crop deserves special attention as wholesome and satisfactory food that

can be grown in many parts of India, particularly in the hill districts, and it can be easily handled by the cultivators. It gives them a substantial reward for their labours, and responds to intensive cultivation and to relatively high manuring. In the peasant countries of Europe, Ireland, Poland and others, potatoes form a large part of the diet.

Two difficulties have still to be overcome. Potato seed of satisfactory quality is not yet available in sufficient quantity to meet the demand and consequently supplies for Bombay and Sind have to be imported from Italy and Cyprus. Satisfactory seed can, however be grown in the hill districts in the Himalayas and Nilgiris, and attempts are being made to produce the necessary varieties in suitable quantity. The second difficulty is in connection with disease : late blight (*Phytophthora infestans*) causes trouble in the hills, and virus diseases are bad in the plains.

The investigations are under the general control of the Imperial Institute of Agricultural Research, Delhi. The first step was to choose the hill station : Simla. Chaubattia, Ramgarh, Darjeeling, Shillong and Kulu were all tried and Simla proved the most suitable so that the work will be done here, the local assistant Mr. Pushkar Nath.

Varieties have been collected from the different provinces ; and new species of Solanum from South America (obtained through Dr. Hudson of the Imperial Bureau of Plant Genetics, Cambridge, and Mr. Salamon (also of Cambridge), the U. S. A. and U. S. S. R. some of these are resistant to frost and some to late blight.

The work has only just started, but it has gone on long enough to show that good setting of the seed can be obtained here and that hybridisation can be properly carried out. The selection of the site seems to have been good and the work to be well begun. Potato breeding experiments are also made in the Nilgiris (page 201).

Wheat Breeding Scheme for Producing Rust Resident Varieties—Simla.

This forms part of Dr. Mehta's investigation on Rust (page 98). The breeding experiments are carried out in the Rust Research Laboratory at Flowerdale, Simla East, by Mr. M. A. Aziz under the joint direction of Dr. Mehta and Dr. Pal. The work was begun in 1935, and a number of crosses have been made which are now being examined for resistance to the rusts. It must be some time before results emerge, but the work appears to be well planned and properly carried out.

DEHRA DUN.

(Visited March 14th and 15th, 1937.)

The Forestry Research Institute was visited as an example of a successful research organisation which has a long record of useful service. Its work joins on with that of the Council in several subjects notably grazing, erosion and insecticidal plants.

In regard to the latter it is desirable that the same methods of evaluation should be used both at Dehra Dun and at Bangalore, and the two chemists should periodically work on the same samples to ensure that they are obtaining similar results.

Here also the difficulty of exploiting experimental results has been met but not yet overcome : ply wood, pulp, and other timber products have been made on the small scale but there is no means of proceeding further and establishing an industry.

Mungpoo Cinchona Plantation (N. Bengal).

(Visited February 26th and 27th, 1937).

The plantation at Mungpoo is under the supervision of Mr. C. C. Calder of the Botanic Gardens, Calcutta, and the resident officers in charge are Mr. S. C. Sen who has a good knowledge of the conditions of growth and production of cinchona ; Dr. Sen the Chemist ; and Mr. Richards, a competent horticulturist.

Only a part of the cinchona used in India is grown in the country and a very considerable amount has to be imported. It is very undesirable that India should be dependent on overseas supplies of so vitally important a substance as quinine, and serious efforts should be made to extend its cultivation so far as is practicable.

The conditions for successful growth of cinchona are generally the same as those for tea, except that they are narrower ; tea is therefore a competitive crop and so long as prices are high the growers will not produce cinchona. In recent years, therefore, the cinchona plantations have decreased in area.

The seedlings are raised in much the same way as those of the tea plant ; they are transplanted into the plantations and after some 8 years the shoots are cut down and bark is striped off and taken to the factory. New shoots then spring up and after 6 years these also are cut down. The economic life of the plant is now ended : the roots are therefore dug out and taken to the factory ; their bark is the richest in quinine.

In the old days the land then reverted to jungle or was planted with timber trees. Now it is put back into short forest, in order that leaf mould may form.

The trees vary in their quinine content. The bark of *C. ledgeriana*, the best variety, on an average contains 4—5 per cent. but individual samples give 7 or even 10 per cent.(1) Seed is saved from these rich yielding plants in the hope that the progeny also will give high yields.

The restriction of the tea acreage resulting from recent trade agreements opens up the possibility of planting more cinchona. I recommend that this question be taken up with the Tea Research Associations at Tocklai and in Travancore.

---

(1) The Malay figures are somewhat higher, and the Java figures higher

ASSAM.

Tocklai Tea Research Station.

(Visited March 1st, 1937).

The Tea Research Station at Tocklai is a private institution maintained by the Indian Tea Association. It receives no grant from the Council(1) though it is associated with the Council in that its Chief Scientific Adviser is a member both of the Advisory Board and of the Governing Body. Its work, however, presents certain special features which give it particular interest and importance. The Staff are in close touch with the cultivators on the one hand and the buyers on the other : they are therefore fully cognizant of the market requirements and of the cultivator's difficulties. The samples of tea produced in the experiments are examined by expert buyers in Calcutta and London, who assign marks expressing the opinion of the market about them. Contact with the tea-growers is maintained by arranging short courses for them at the station : by inviting them to an annual conference at which the programme of work is discussed ; and, as far as circumstances permit, by arranging for the staff to visit and advise them on their own plantations. The task of keeping in touch with the tea growers is enormously facilitated by the circumstances that they are mainly educated men resident on the plantation, themselves actively concerned in the cultivation of the crop, and anxious to improve their practice in every way possible. Further, they are in a position to adopt new method as soon as their superiority has been proved. This of course is an advantage that few other research stations enjoy.

The Station has the further advantage of perfectly free choice of staff so that it can select the best men available : the programmes of work are carefully thought out and directly related to the most important of the grower's problems ; and the staff confine themselves to a few important problems which they study thoroughly, instead of scattering their energies over a wild field.

The station is under the general charge of Mr. P. H. Carpenter and is organised in 5 branches. Chemical, which includes the field work carried out on the well equipped experimental farm ; Entomological, Mycological, Bacteriological and Botanical.

The Chemical laboratories and field experiments are in charge of Messrs. H. R. Cooper and C. J. Harrison.

The field experiments are well done. The design is worked out in conjunction with the Rothamsted Station and the execution is beyond reproach. These experiments have shown that organic manure has no special advantage for tea in spite of the fact that most tea soils are poor in organic matter : sulphate of ammonia is the most effective source of nitrogen. The plouging in of a short term green manure crop gave no increase in yield, but the long term crop *Tephrosia candida* seemed to be better. Both types while growing depressed the yield of the tea, but after they were dug in the yield increased. With short term crops the increase just about

(1) The Governments of Bengal and Assam usually contribute a total of about Rs. 4,000 towards an annual expenditure of about Rs. 2,50,000.

balanced the depression so there was no net advantage ; after the longer growing Typhrosia plants were removed, however, a substantial increase in the tea crop followed.

Cultivation beyond what is necessary to keep down weeds fails to increase the crop ; the elaborate cultivation, which some of the good growers like to give, proved unnecessary. Similar results have been obtained with other crops at Rothamsted and some of the American experiment stations. The best economic results were obtained by giving the minimum of cultivation but supplying fertilizer containing 80 lb. nitrogen per acre ; in these circumstances the bushes grew so well that they touched each other smothered the weeds and so rendered further cultivation unnecessary and indeed impossible. The pruning plane is here about 2 ft. 6 inches to 3 ft. 6 inches in height.

The work on diseases and pests is particularly interesting because it is based on the recognition that a knowledge of the conditions under which damage is done by the pest is far more important than studies of the detailed life history of organisms concerned. Disease organisms occur in all plantations, but only in suitable circumstances do they do harm. Careful records are kept, therefore, of the incidence of the various diseases and special note as to whether the disease progresses or dies out as the season advances, so as to discover the conditions favourable or unfavourable to the attack of the organism. Favourable conditions are then as far as possible avoided; direct treatment is adopted only when other methods fail. As an example—red rust (*Cephaleuros*) used to do much damage to tea. The records, showed, however, that it was harmful only in conditions of defective drainage. The drainage was therefore improved and the disease ceased to be serious. The number of bushes infected may not have altered, but the conditions no longer allow sufficient multiplication of the organisms to do serious harm.

Another interesting investigation deals with the incidence of disease after the heavy pruning necessary for the proper management of the plant. Sometimes disease attacks are very severe, at others they are light. Mr. A. C. Tunstall showed that severe attacks are associated with low reserves of starch in the root and light attacks, or freedom from attack, with larger reserves. He devised a very simple test which the grower can himself apply to find out whether the reserves are adequate permit of the usual pruning.

In the Bacteriological Laboratory some good work has been done by Mr. Benton on the influence of bacteria in the curing of the tea. This process is essentially enzymic, but bacteria invariably present in the buds are always liable to give trouble. Some of the worst of them persist on the curing floor even after it has been apparently well cleaned. A very simple and elegant test of the cleanliness of the floor has been worked out by Mr. S. F. Benton : this enables the manufacturer speedily to ascertain whether more drastic cleaning is necessary.

The Botanist, Mr. W. Wight, is in charge of the work on selection and breeding of tea plants ; this is very difficult, because they

easily bybridize. Of the various possibilities the most promising seems to be to set up clones.

Soil and manurial investigations are made by the chemist, Mr. Harrison, who has brought out the very serious difficulty of relating chemical composition with quality assessed by the expert buyers. Simple relationships can be found where teas are grown under almost identical conditions, but not when samples from different plantations are compared.

One of the most interesting of the discoveries of the Station has been the necessity for acidity of the soil : a pH value of about 5.0 to 5.6 seems to be the most favourable and at pH 6 difficulties begin to arise. Methods are therefore investigated for increasing the degree of acidity whenever this is necessary.

The success attained by the Station among the growers has been very marked, and I consider it would be an advantage if a certain number of Indian workers could receive some training at Tocklai. The work is of course specialised, but the methods of discovering and attacking the important problems are very sound and could well be adopted in other centres of agricultural investigation.

Jorhat Farm.

(Visited March 1st, 1937.)

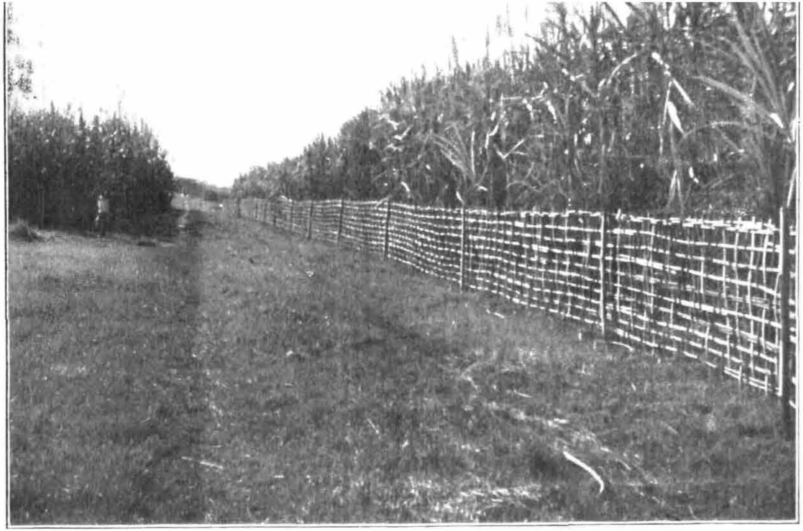
Sugar Cane Investigations.

GRANT: Rs. 63,000 spread over 5 years.

Some 36,000 acres of sugar cane are grown in Assam: this area has remained practically unchanged for the last 30 years. The crop is entirely rain grown; there is no irrigation. The plant cane is usually followed by two ratoon crops, then the land is abandoned for a few years, after which it is again cropped with sugar cane.

The purpose of the Jorhat experiments is to work out effective schemes for the cultivation, manuring and management of the cane and to find suitable varieties. Canes from Coimbatore are tested and suitable varieties are multiplied for distribution ; no viable seed can be produced here and all new varieties must be imported. About 6 or 7 years are usually needed to get a new variety to the cultivator. Improved varieties are adopted without difficulty, and I was informed that more than half the area planted is under the new sorts, but there is clearly much work yet to be done, for while at the station the yields are about 25 to 30 tons per acre, the cultivators commonly obtain only about 8 to 10 tons.

Cultivation and manurial experiments of local interest are also done. Combined varietal and manurial experiments are made using 7 varieties replicated 6 times—3 out of the 6 crops receiving cow-dung and oil cake manure, the other 3 receiving none. The effects of artificial fertilizers should also be studied. I noted that green manuring with cow peas was adopted as of proved advantage, while at the neighbouring tea research station at Tocklai no benefit could be discovered. There is no necessary discrepancy here because of the



Sugar cane Experiments Jorhat.
Protection against jackals.

difference in cultivation conditions but experiments should be started to discover whether cow pea manuring is really beneficial at the Jorhat Station.

The *Entomological Laboratory* is in charge of Mr. K. C. Sharma who is studying the incidence of insect attack on the sugarcane using light traps to catch the insects(1). He is also making studies of bees.

In the *Mycological Section* various fungal and bacterial diseases found on the farm are studied.

In the *Chemical Laboratory* Mr. Phookan among other activities is making a soil survey of the sugar cane tracts. Sugar cane in Assam is rain-fed and there seems to be considerable possibility of extending the area under cane; a considerable amount of land said to be suitable is not at present fully used.

It will be interesting to see how far the sugar cane industry develops in Assam. At the outset expert opinion was rather against it; the disadvantages being low tonnage, unhealthy climate, difficulty of road communication and scarcity of labour. There is the further difficulty that the sugar cane is much liked by jackals so that it is necessary to grow varieties with rind sufficiently hard to be safe from them. Several of the Coimbatore seedlings combine this character with high yielding capacity.

The experiments seem to be better conducted than they were in the beginning and their small cost relative to the acreage of cane raises the hope that they may justify their continuance.

Rice Investigations.

Deep water paddy: Habiganj, Surma Valley.

GRANT : Rs. 1,17,882 for a period of 5 years.

I was not able to visit this station, but Mr. Majid, the officer in charge, met me at Sylhet and explained the results.

Three types of rice are grown in Assam:—

(1) Spring or boro;

(2) Summer or Aus, of which there are three sub-groups: Dumai, Murali and Changhir;

(3) Winter rice subdivided into Sail, for which the optimum water depth is about 3—6 inches; and the deep water or long stemmed Aman paddies.

The Aus and Sail varieties are studied by Dr. Mitra, as part of the Departmental work; Mr. Majid is concerned only with the Boro and Aman varieties.

The deep water or long stemmed paddies, for the study of which the grant is given, are among the most remarkable plants in India. They are sown about March on the low lying land, and by June, when the monsoon floods come, they have attained a stage of such vigorous growth that they can keep pace with the rising water level even though

(1) See page 117.

the rise be as much as 6 to 12 inches in 24 hours and the final depth attain to 20 feet.

When the water recedes at the end of the flood season, it leaves behind masses of entangled lodged plants, 12 or 14 feet in length, which makes the experimental work very difficult; a special technique has to be devised.

In addition to his principal work of selection of pure lines for multiplication of promising strains and for hybridisation, Mr. Majid takes daily measure of the growth rates during the flood season by means of long bamboo canes, the work being done from a boat. The data are to be properly worked up in Professor Mahalanobis's laboratory and should give some very interesting results.

Mr. Majid's work appeared to me to be very good.

Potato Experiments—Upper Shillong Experiment.

(Visited March 3rd, 1937.)

The hills round Shillong are very suitable for the growth of potatoes and the hill people have developed a method of shifting cultivation called jhuming, in which branches of trees are spread over the virgin soil and then fired; the heat makes the soil friable so that it can easily be cultivated. Potatoes are then planted. Two crops a year can be obtained. The main crop is planted in February and March, then harvested in July and August. A second crop can follow immediately and be harvested in November. The main crop rarely exceeds 3 tons per acre on cultivators' land, though it amounts to 4 or 5 tons on the experimental farm; the winter crop is used for seed.

The experiments consist in testing different varieties and various fertilizers. The land, however, is very uneven and quite unsuited for this purpose. Unfortunately the crop is subject to a good deal of disease, particularly *phytophthere*, virus diseases, various rots on storage, *Fusarium*, etc., and in extreme cases as much as 20 per cent. of the seed may be lost. A Mycologist is badly needed here: he should work under the guidance of the Plant Pathologist at the Central Institute.

At present there is no scheme in operation under the Council, but when the potato investigations in the Nilgiris and at Simla are further advanced, the possibility of including Shillong in the scheme should be considered. The crop has considerable importance in the Province, being grown even by the smallest cultivators; in addition, important supplies of seed might be obtained from here if the difficulties caused by diseases could be overcome.

Assam Fruit Research Scheme the Khanpara orchard.

Grant: Rs. 37,424 spread over a period of 5 years, to provide a horticultural assistant for the Director of Agriculture, Mr. J. N. Chakravarti. The main item is the work on citrus.

Travellers along the magnificent new road from Shillong to Sylhet are familiar with the sight of oranges brought by cultivators to collecting stations where they are loaded on to lorries for delivery to the town. The citrus trees are probably indigenous; hitherto they have never been adequately studied either as fruit producers or as stocks on which to bud other varieties. The Khasi orange seems to have definite possibilities which will now be investigated.

Bananas are also commonly grown, and there seems great scope for their improvement.

BENGAL.

Calcutta University and other scientific Institutions.

Calcutta is one of the most important centres of scientific activity in India and several of the investigations are supported by the Council or bear closely on its work. I made four visits to the city and on each occasion spent most of my time with one or more of the scientific workers so as to gain a fuller knowledge of what they were doing.

Colloid Soil Constituents—Professor J. N. Mukherjee.

(Visited January 18th, 1937.)

(Grant sanctioned : Rs. 32,910 spread over a period of 8 years.)

It is now widely recognised that the colloidal constituents of the soil are responsible for many of its most important properties including its power of holding water, of forming crumbs and tilth, and its general relations to plant growth. In all countries where agricultural science is seriously studied investigations on the soil colloids are in progress.

The subject, however, is extremely difficult, requiring for its investigation not only training in physical chemistry, which any intelligent chemist could acquire, but a gift for research which is extremely rare. Fortunately Professor Mukerjee possesses the necessary qualifications and his investigations on soil colloids are recognised in Europe as being both sound and important.

His programme is the study of the properties of the hydrogen (acid) clays. He began with the simplest case; a non-colloidal sparingly soluble acid, cinnamic acid; he determined its titration curves by the potentiometric method and studied the influence of the solid phase. In absence of the solid phase the curves could be interpreted in the usual way and the dissociation constants satisfactorily obtained, but in the presence of the solid phase no constants could be obtained, the values differing at different parts of the curves. He then proceeded to the more complex case of relatively simple colloids : palmitic acid and silicic acid sols and obtained their titration curves, studying their divergencies from the simpler case. Finally he proceeded to the far more complex hydrogen clays and studied the mobility of the hydrogen ion under different conditions.

Professor Mukerjee is fortunate in having the help of a group of competent students and assistants, and the investigation is not only adding to knowledge of the soil but is also affording a sound

training to a number of promising young men. It should certainly be continued.

In view of the very good physical laboratories available in Calcutta it is very desirable to make physical studies of the clay by the modern X-ray and optical methods which are now giving much new information on the subject. These, however, should not be regarded as a mere extension of the chemical investigations but as work for an experienced and able physicist.

Professor Mukerjee is the only man in India—or indeed in the whole of Asia—who is working on these particular lines and in consequence he has but little opportunity of discussing his experiments. With so complex a substance as acid clay there are always difficulties in interpreting results and I recommend that Professor Mukerjee should be given facilities for proceeding to England for six months in order to settle down in a good soil laboratory, preferably at Rothamsted, and repeat some of his experiments there, so that the significance of the results can be discussed with others engaged in similar investigations. In view of the good start that has been made I consider that a period spent in this way would prove very valuable.

Statistical Investigations : Professor P. R. Mahalanobis.

(Grant sanctioned : Rs. 52,625 to be spread over 10 years.)

These are among the most interesting I saw in India.

Professor Mahalanobis' investigations have largely been shaped by his two great teachers: Einstein and Tagore. He began as a physicist, but under Einstein he naturally became attracted to the mathematical side, and developed a flair for mathematical statistics. His first important studies were on rainfall and floods in North Bengal in which he showed that the damage was done, not by water coming from outside, but from the rain falling within the area. It has been proposed to set up dams and reservoirs to keep back the outside water : his investigations showed that the proper treatment was to provide better drainage. Later investigations dealt with the Orissa floods and with the need of storing water for the Hoogly-Howrah irrigation scheme.

His present investigations fall into three groups:—

(1) *Pure statistics.*—This section is in charge of Mr. S. C. Bose who has used successfully hypergeometric methods on a number of problems, some of anthropological, others of agricultural interest. Five characters of four varieties of Aman rice were studied and from investigations of the differences it is hoped to arrive at some mathematical description of a variety.

With characteristic enterprise Professor Mahalanobis has started a mathematical journal Sankhya in which these necessarily abstruse papers can be published. This deserves more financial support than it receives.

(2) *Agricultural problems.*—This section is in charge of Mr. S. S. Bose. Here the field experiments on rice at Chinsura were designed and the results worked out: two feeding experiments were

also designed for Dacca: one was to ascertain the digestibility of protein in straw and in cake, both being fed together; the other was to compare two foods as milk producers when fed to dairy cattle.

(3) *Village surveys.*—From Tagore Professor Mahalanobis imbibed wide humanitarian teachings which gave him an abiding interest in village welfare, so that he has devoted considerable time to developing methods for making proper surveys. There are some 90,000 villages in Bengal, and the task of surveying them all would be hopeless. Chance selection of individual villages might lead to very misleading results. It is proposed to survey one village in a hundred by welfare workers, making a properly randomised selection: the cost is estimated at about Rs. 200 per village. Professor Mahalanobis lays great stress on the need for the welfare worker being a true resident in the village and not a mere visitor: he should also be obviously earning his own living by starting a school, giving medical aid, selling medicines, seeds, yarn, etc., or marketing village products; but he must also be given a subsistence allowance for the first year. The central organisation must of course keep touch with him and look after him; if one village will not receive him, he must be transferred to another.

Professor Mahalanobis recognises, however, that the lack of suitable workers is more serious, and more difficult to remedy, than lack of funds.

In addition to these research activities he is actively occupied in the training of young men who can apply statistical methods to agricultural problems. The subject being new it does not come in to the ordinary University course except in an elementary way, and Professor Mahalanobis has good facilities for giving special additional training. It is desirable that such facilities should be available in India, the more so as his old students can always consult him in any difficulties they meet in the course of their work.

The work of this section is so good and so helpful to investigators in agriculture that it should certainly be continued, and sympathetic consideration should be given to the possibility of extending it. The Statistical problems raised by the Council's work are so numerous that the Council's statistician could not possibly deal with them all, and it is very important that the additional help which Professor Mahalanobis renders should be available.

Botany Department.

This department is housed in the former residence of the late Sir T. N. Palit, one of the patrons of the University, who gave his residence and ground for the purpose. The Head of the Department, Professor, S. P. Agharkar, is an active organiser. In addition to purely botanical studies the investigations include some that bear on agricultural problems: cytological studies by P. N. Bhaduri and P. K. Bose and Miss Sally Meyer: algae of paddy fields by J. C. Banerji, the Keeper of the Herbarium; the physiology of parasitism of certain fungi by P. V. Ghabale and H. K. Barna: and water requirements of the rice plant by B. N. Ghosh. For this latter special cement tanks have been constructed in the grounds, but the work is as yet

in its early stages. It is proposed to study water hyacinth, a terrible water weed that does increasing damage in water courses and tanks.

No scheme fostered by the Council is at present in hand, and therefore I make no report on the very interesting work being done here.

Zoological Department.

Professor H. K. Mukherji is head of the Department and showed me two investigations of Agricultural interest though both outside my province ; I must, however, mention them because of their importance. The Indian silk worm spins a cocoon containing about 500 ft. of thread, yellowish in colour. The Italian silk worm on the other hand spins a cocoon having 800 ft. of thread which is white. These differences are being studied and the knowledge gained may lead to improvements in the making of Indian silk.(1)

The work on the cultivation of edible fish is fostered by a grant from the Council, but as the subject is outside my purview I cannot report on it. I can only say that I regard the subject as very important : the stocking of the village tanks with fish would not only provide the villagers with a food containing a much needed supply of good quality protein, but would also help in keeping down mosquitoes.

Calcutta—School of Tropical Medicine.

(Visited January 19th, 1937.)

(*a*) Cultivation of Medicinal Plants ;

(*b*) Study of Food poisons :

Grant sanctioned : Rs. 62,860 spread over 5 years.

The purpose of the first part of this scheme is to study the medicinal plants growing in India ; it was hoped also to encourage their cultivation but this has proved very difficult. India is rich in medicinal plants, and Colonel Chopra began by collecting the scattered information already existing and putting it into a form available to medical men generally.(2) With the assistance of Mr. R. L. Badhwar, the Botanist, he is now widening the scope of the enquiry and seeking new information about the occurrence of medicinal plants and also about their therapeutic action. This will necessarily take a good deal of time.

Unfortunately through no fault of Colonel Chopra the Agricultural Departments have hitherto shown but little interest in the possibility of cultivating medicinal plants : a few have experimented with one or two plants but there has been no systematic study to correspond with the laboratory work. Yet if the full advantage is to be gained from the investigation it is essential to find out whether the plants can be grown in practice and if so whether they lose their

(1) The Bengal Department of Agriculture has done some good work—recently transferred to the Bengal Industries Department—on the improvement of Indian silk worms. Miss Clegg's studies of the various races and hybrids deserves mention.

(2) See his useful volume Indigenous drugs of India, Art Press, Calcutta, 1933.

so-called "active principles" on cultivation—as does sometimes happen. The Council is dealing with this matter.

The investigation of food poisons has proceeded slowly. There are in India a number of food poisons about which little is commonly known: poisoning of the nature of ergotism is occasionally reported as the result of eating infected barley, oats, or wheat; the pollen of certain grasses has harmful effects; and lathyrism results from a too exclusive Lathyrus diet. At the present time epidemic dropsy is being studied: this is usually attributed to some infection of food, especially rice and mustard oil. Investigations of this sort are necessarily slow and there is no point in trying to hurry them.

The School of Tropical Medicine is well equipped for the enquiry. It has good departments of Chemistry, Pharmacology, Pathology, etc., and a competent staff, having the advantage of Colonel Chopra's guidance and accumulated experience in regard to standard medicinal preparations. The work should certainly be continued.

An investigation in the Chemical Department on *Saussurea lappa*—a potent insecticide in addition to its other properties—suggests that this Department could render useful help in connection with the Council's plant insecticide investigation.

Physiology of the rice plant.

In September 1936 the Council approved, subject to the Governing Body's sanction, a grant to Dr. B. Sen, of the Vivekananda Laboratory, Calcutta—a private institution not forming part of the University—of Rs. 7,500 to be spread over three years for the purpose of studying the effects of various cations and anions on the protoplasm of root hairs. I was not able to see this work, and cannot therefore report on it.

Rice Experiments, Chinsurah.

(Visited January 21st, 1937.)

Bengal has a larger area under rice than any other Province or State in India: no fewer than 20.7 million acres out of a total of 79.5 million acres of British India. Nevertheless in average years the crop is insufficient for the needs of the Province, particularly in the eastern part, and rice has to be imported from elsewhere; only when unusually high yields are obtained does the supply meet the demand. Parts of the west of the Province usually have a surplus which, however, is not easily sent eastwards because of transport difficulties.

There seems little scope for increasing the area under rice and consequently the Department is aiming at increasing the yield per acre by the introduction of improved varieties and methods. The present work is based on the classical investigations of G. P. Hector.

The problems of eastern and northern Bengal are studied at Dacca where rice breeding has been going on for some 25 years. For western Bengal two stations have been set up: one at Bankura, about 100 miles north-east of Calcutta, and the other at Chinsurah,

about 25 miles to the north of Calcutta. The Council has made a grant of Rs. 1,56,322 to be spread over five years for the work of these two stations. The experiments are under the supervision of Dr. S. Hadayatullah ; the Chinsurah farm is in charge of Mr. S. C. Chakravarty with Mr. E. A. R. Banerjee as Chief Assistant, and the Bankura farm is in charge of Mr. K. C. Banerjee. I was not able to visit the Bankura farm but the Officer in charge met me at Chinsurah and showed me the results of the experiments.

There are some differences in conditions between these two stations. At Chinsurah the land is flat and is irrigated : at Bankura the land slopes and is terraced ; necessitating special arrangements of the plots ; there is no irrigation, the water supply is entirely from the rain.

At both stations both Aus and Aman varieties are studied, the Aus being high-land types grown with rain only, sown in April, usually having a fixed life period of 90 to 115 days independent of the time of sowing ; while the Aman varieties are low-land rices, sown in beds in June, transplanted in July ; they have a constant flowering date in mid-October independent of the time of sowing ; and are harvested in November-December. Economically, they are the more important, covering about three quarters of the area under rice.

As at other stations, a considerable collection of varieties has been made out of which the separate types have been selected. The agricultural characters are then studied and promising strains are either multiplied for distribution or used as parents for hybridisation.

Before beginning the field work a very striking uniformity trial was made at Chinsurah—one of the most impressive that has been carried out in India. Professor Mahalanobis designed it and worked out the results deducing valuable information in regard to the optimum size and shape of the plots. Another interesting experiment, also designed by Professor Mahalanobis and made at Bankura, shows the effect of various treatments, such as age of seedling at transplanting, broadcast sowing, and dibbling, with different varieties, while at Chinsurah an even more complex experiment is carried out—three varieties tested against four ages of seedling, 3 spacings and 3 different numbers per seedling per hole.

These complex experiments have several statistical advantages, but beyond a certain limit the practical difficulties become so great that they are liable to break down ; nothing but actual trial can show where the limit lies and it varies with the officer in charge.

At neither station are any manurial experiments made as yet though there are pot experiments at Bankura.

The work here is well done and the proximity to Calcutta enables Professor Mahalanobis to give the necessary assistance on the statistical side.

Dacca University.

(Visited March 5th—7th, 1937.)

When the Dacca University was established in 1921, the old Dacca College Chemical Laboratories were considerably extended

under Professor Ghosh and further developments have gone on since that time.

Two of the Council Schemes are carried out here dealing respectively with the nutrition of rice and the mechanical analysis of lateritic soils.

Biochemical work on rice.—Dr. Kalipada Basu.

GRANT : Rs. 21,600 for 5 years.

This work consists in two parts : chemical analysis of both Aus and Aman varieties ; and feeding experiments, by both balance sheet and growth rates methods. It is subsidised from the Indian Research Fund Association and is being done in association with Dr. Aykroyd and with Professor Wilson who is in charge of Hygiene at the School of Tropical Medicine, Calcutta.

Dr. Basu has found some interesting differences in the cystine content of the Aus and Aman varieties ; the former containing less than the latter. The work seems to be good, and the linking up with the medical side is a particularly sound feature.

The Council's other schemes on quality in rice, and the proposed scheme for Sabour, should be reviewed in the light of these investigations to see if they are really necessary. The subject is of course of great scientific and medical interest but it need not be taken up at more than one Institute. On the other hand the important question of finding practicable methods of supplying the nutrients in which rice is known to be deficient must be studied at a number of centres.

The nitrogen nutrition of rice.

This is being investigated in the Chemical Department by Mr. Prai Kumar De. The problem is interesting, though largely academic. The export of rice from Burma and Bengal has gone on for many years, removing much nitrogen from the soil. No nitrogen is ever put back, and yet the soil fertility is apparently unimpaired ; there must therefore be some recuperative agency. This is an old problem in agricultural chemistry : it was stated very much in these terms by Berthelot in 1885 and it has been continuously discussed ever since : the explanation now given is that some of the soil organisms fix gaseous nitrogen from the atmosphere. The action has been well studied in western countries, and Mr. De is proposing to investigate it here ; he is examining the possibility of fixation by the combination of Algæ with bacteria, an action shown to take place by Kossowitsch in 1894 and much studied ever since. He is at present working under Professor Fritsch at the Queen Mary University College, London, endeavouring to separate algæ from bacteria so as to ascertain what part each plays in the process. I learn from Professor Pritsch that Mr. De is making satisfactory progress with the investigations and I recommend that he be given such additional time as is necessary for their completion.

The investigation is very suitable for a University laboratory. It could be extended to include a repetition of the work of Harrison and Aiyer on the part played by algæ in supplying oxygen to the

rice roots—also a matter of scientific interest. As a University problem the question whether the work is likely to lead to practical results does not arise : in Java, where the investigations are in the main practical, the function of the algæ in paddy fields is no longer studied as they are not regarded as playing any part that can be controlled.

Respiration of rice plants.

In addition to the Council's Scheme there are other investigations proceeding in Professor Ghosh's laboratory, among them one on respiration and assimilation by rice plants, using some ingenious micro-chemical methods designed by Professor Ghosh, who is very skilful in these matters.

Jute.

A considerable amount of interesting work is being done in the chemical department under Professor J. C. Ghosh on the chemical and physical-chemical properties of jute. This subject comes under the purview of the new Jute Committee, and is therefore outside the province of the Council and of this report.

The investigations of red soils.

GRANT : Rs. 71,479 spread over 8 years.

The red or lateritic soils of India form a very important group which is being studied by Dr. Ashutosh Sen with a staff of assistants.

A striking characteristic of these soils is that while they are rich in the clay fraction (particle size : below .002 mm. diameter), containing up to 40 per cent. of this finest material, they can still be cultivated when wet without having their texture ruined. As a rule they are not very fertile.

He has designed a method for the mechanical analysis of these soils. It is well known that the international method is not entirely suitable for laterites and lateritic soils and when Dr. Ashutosh Sen came to Dacca in 1930, he continued some investigations he had already begun at Rothamsted and showed that the international method could be used though it was not at all convenient. In the first place it requires the use of hydrogen peroxide as an oxidizing and dispersing agent, and in India this reagent is both expensive and unstable. He therefore set out to find a substitute and showed that alkaline permanganate is quite satisfactory, being inexpensive and free from objectionable properties in use.

He is also studying the general chemical and physical properties of these soils, and in view of the importance of the group, and of the special knowledge which he has acquired I recommend that he be allowed to devote himself to this work, and that he should establish contact with workers on similar soils in the West Indies and Central Africa so as to see how the Indian soils compare with these other soils in chemical and physical properties. The problems involved are of

wide-spread scientific interest, and in view of the circumstances that the name "laterite" originated in India as a result of Buchanan's early observations, it seems only fitting that the Indian soil scientists should continue to hold an important position among the workers on this particular group.

Considerable data have been accumulated relating to the physico-chemical properties of the clay in these lateric soils, and it is advisable that these should be statistically analysed either by the Council's Statistician or in Professor Mahalanobis' laboratory.

Organic matter in the soil.

GRANT : Rs. 11,200 spread over 5 years.

The programme includes estimations of carbon and nitrogen in various fractions of the soil organic matter ; determinations of groups or elements present in a so-called "humic" acid obtained from peat ; and estimates of the loss of the various organic components of straw during humification.

These are standard methods which have frequently been applied to soils in other countries though unfortunately without giving much information. The problem is one of the most difficult in the whole range of soil chemistry because of the extraordinary complexity of the mixture and the difficulty of ascertaining whether any particular substance isolated actually existed in the soil or is only a decomposition product resulting from the chemical treatment.

At the time of my visit the Chemist was endeavouring to extract organic substances of the soil by the Schreiner and Shorey method devised in 1910. The workers should study the recent literature and adopt some of the more modern methods.

Investigations of the nitrogen cycle in paddy soils.

Studies in the changes of the nitrogen compounds in paddy soils are also being made ; these are exceptionally difficult, owing to the variability of the soil, and I am not satisfied that the sampling technique is adequate. The question should be discussed with the statistician and a method worked out that avoids the errors due to differences in compactness of the soil at different dates of sampling, and also allows the error of sampling to be estimated on each occasion so that a valid estimate can be made of the significance of the analytical figures.

No evidence could be found in support of Professor Dhar's claim that sunlight brings about nitrogen fixation in the soil.

The Dacca Farm.

The farm is not part of the University but is under the Department of Agriculture. Hitherto the research work has been in charge of Mr. M. Carbery, but now that he is appointed Director of Agriculture he will have less opportunity for close supervision. The Council gives a grant of Rs. 22,570 spread over 5 years for the study of the physical properties of the soil of the farm, the work being done by Babu Manindra Nath Chakladar under Mr. Carbery's direction.

A number of determinations have been made of soil moisture, rates of evaporation, etc. It is at present a little difficult to see where this work is leading, and if Mr. Carbery finds it necessary to give up the active direction, I suggest that it be put under the control of the Punjab Irrigation Station where a somewhat similar problem is under investigation.

Rice Improvement.

Nearly 1,000 classified pure line strains of Aus (highland autumn paddy) and of Aman (lowland winter paddy) are grown, and their agricultural and botanical characters noted. From these desirable strains will be selected. This work, like that at Chinsurah, is a continuation of Hector's classical work on the Eastern Bengal rices ; it is on similar lines to that at Chinsurah : it is not aided by the Council.

Dacca Sugarcane Seedling Testing Station.

GRANT : Rs. 24,850 spread over 10 years.

The purpose of this work is to test sugarcane seedlings with a view to finding their suitability to various conditions in Bengal. Coimbatore cane Co213 has proved successful and it is used as a standard for testing new seedlings. A certain number have already been picked out as deserving further investigation.

Linseed improvement.

The oil content of Bengal linseed is very variable ranging from 35 to 42 per cent. It is proposed to collect pure types from Bengal and also from other provinces to study their agricultural properties and select varieties that could be recommended for general cultivation. It is very desirable to improve the linseed crop and this work is worthy of support.

Krishnagar Fruit Station : Nadia District.

GRANT : Rs. 57,030 spread over 5 years.

This station has only recently been started and I was unable to visit it. The programme consists in varietal, manurial and propagation trials with mangoes, papaya, pineapples, leitchis, guava, plantain and citrus fruits.

Power Cane Mills for Crushing, gur boiling plant.

The Council has given grants to the United Provinces, Punjab, Bihar and Orissa and Bengal for doing experimental work on cane crushing and gur boiling plants. The Bengal grant amounts to Rs. 5,703 spread over 3 years.

The importance of replacing the present bullock-driven mill by power crushing plant arises from the congestion of farm work in the early part of the year. In Bengal the very large paddy crop ripens mainly in December and its threshing begins then and continues into

February or later. Also the kharif season comes early and sowings begin at the end of February, and continue till May or later. The cultivator is therefore very busily occupied at the beginning of the year and when in January the sugarcane starts ripening he is unable to spare his bullocks for working the crushing mill. An effective power mill would be very valuable. The Bengal bullocks are in any case among the poorest in India.

The Visva-Bharati activities.

At the invitation of Dr. Rabindranath Tagore I was fortunate in being able to visit the Visva-Bharati, Santiniketan and to spend some time both there and in the Sriniketan section where a serious effort is made to devise methods for improving the life of the village in all its aspects, including agriculture, village industries, organisation of social services and above all the instilling into the young people of the village the sense of their responsibility for improving the conditions in the villages. A number of experiments are being made with the purpose of finding the best way of educating the children in the village ; it is certain that the ordinary literary education of the town school is quite unsuitable. Some interesting village surveys have been published which include not simply the economic factors, but go fully into questions of social conditions, religious observances, etc. These village surveys have the advantage of being supervised by Professor P. C. Mahalanobis, thus ensuring that the statistical basis is sound.

The rural economic research which was proceeding at the Institute is in three directions :—

(1) Agricultural production ;

(2) Rural surveys ;

(3) Study of the village psychology and human relationships.

The work, however, is not confined to the Institute : it extends to the villagers themselves and I had an opportunity of seeing something of it. This outside work continues the purpose of the Institute : it aims at improving the material conditions in the villages by raising the standard of farming, introducing new varieties and improved methods, improving also the water supply for village use and for irrigation by clearing out the old tanks that have been silted up through negligence. Over a hundred irrigation societies have been organised for this purpose and the total area irrigated has been 1,283 acres. The Visva-Bharati Co-operative Bank has 268 affiliated primary societies, mostly credit with unlimited liability, 42 irrigation societies and one co-operative store. A feature of the work which impressed me very favourably was the deep interest taken by the workers in the welfare of the cultivators. They are inspired by the true missionary spirit and they recognise that the surest way of accomplishing their purpose is to organise the villagers to improve their own conditions. The work is done by the villagers themselves under expert guidance from the Institution's staff, and inspection of two of the villages showed that the cultivators have been made sufficiently interested to accomplish a great deal without any other reward than the improvement of their village. Roads have been made and drains constructed and the villagers have been taught to keep their villages clean.

Considerable attention is devoted to the handicrafts of the village. Weaving and leather work have both been considerably improved and a new industry—batique—has been introduced. Further, the cleaning out of the old bunds and the improvement of the channels for irrigation and of the roads, has given the cultivator greater possibilities of using his land to advantage.

The Council has given a grant to Sriniketan for working out methods for the systematic improvement of village life. Methods adopted in other countries are studied, but it is recognised that new methods must be evolved suited to Indian conditions.

The statistical side is under the supervision of Professor Mahalanobis.

BIHAR.

Pusa.

Imperial Research Institute Botanical Substation.

(Visited February 18th, 1937.)

Fortunately neither the botanical laboratories nor the plots suffered during the earthquake, and the work is continuing under Mr. B. P. Pal. Like the Station at Karnal, this is an extension of the Delhi Institute available for general agricultural botanical purposes. There are obvious advantages in establishing a substation here and I recommend that it be put on a permanent basis as early as is convenient. Mr. Pal is concentrating on two problems, the search for varieties of wheat resistant to rust, in association with Dr. K. C. Mehta of Agra ; and for varieties of potatoes resistant to late blight. This latter problem is more difficult than it appears, but he is using as parents certain varieties from South America which, however, though resistant, possess undesirable characters that have to be eliminated.

He is working also on the mosaic diseases of tobacco, of which he has found 5 types, 4 of which seem to be distinct while the 5th is a mixture of two others.

This work appears to be quite good.

The Sugarcane Research Scheme, Bihar.

Musheri Research Station.

(Visited February 18th, 1937.)

Grant : Rs. 2,25,850 to be spread over 5 years.

Sugarcane Specialist : Mr. K. L. Khanna.

The programme consists mainly in selection of more suitable varieties for the different areas of the Province, the finding of disease resistant varieties, and of early and late maturing varieties.

This station suffered very badly in the earthquake of 1934 and many of the plots were damaged.

Mr. Khanna is making numerous studies of the relation between the various properties of the cane, with the view of finding early indications of yield capacity. Thus he finds that the weight of dry matter per plant during July and August is highly correlated with the final yield of sugar in the following February : a series of relationships of the sort would enable good canes to be selected at an earlier stage than at present. Under present methods 7 years must elapse between the production of a new cane and its confident recommendation to cultivators. For the first 3 years it is confined to the nursery ; in the fourth and fifth it goes into field trials at the station, in the fifth and sixth it can go to the mill for mill trials ; and in the seventh it can be distributed to various centres. The work could be considerably lightened if good correlations could be traced between properties showing in the seedling stage and the desirable characters required in the field crop. Further he has shown that the yield of sugar in February is closely correlated with the readings given by the pocket refractometer of samples of juice extracted with a syringe during the preceding growing season. From these readings he is working out a prediction equation to show the grower what yield he may expect, and he is simplifying both syringe and refractometer with a view to making them more convenient for use in the field. He is also investigating the possibility of testing the vigour of canes by injecting various salts and observing their effects on the leaf. If these tests should prove to be valid they would be very helpful to the breeder. Chemical studies are being made on sampling technique and on the progress of ripening and the maintenance of juice quality.

Mr. Khanna is also making studies of drought resistance. This district of northern Bihar is peculiar in that most of the sugarcane is grown here without irrigation : out of about ½ million acres under cane in Bihar about 350,000 are rainfed. The really important test of the different varieties is their behaviour during the dry season. Almost any variety grows well during the monsoon, but the crucial test is the growth during the dry five months from February to mid-June, when the canes have no rain but are dependant entirely on soil moisture.

Some varieties of sugarcane ripen in Musheri and produce viable seed : it would be possible to breed sugarcane if this were ever desired.

Like several other of the younger workers I met, Mr. Khanna is interested in modern statistical methods and has taken much trouble in trying to understand them ; he is an ingenious experimenter and I was favourably impressed with his work. He will do even better when he can concentrate on one or two problems instead of scattering his energies over many. *I recommend that at an early date he should* be sent to England for a term of study in the Statistical and Crop physiological Departments at Rothamsted.

This part of Bihar is the old indigo-growing region, and some of the European planters still remain. When indigo cultivation became unprofitable they took instead to sugarcane. Their standards of cultivation and management are high and they fully understand their work. Further, they adopt a method much used for the indigo crop : they contract with the factories to supply a large proportion of their requirements, growing a good deal themselves and arranging

with the surrounding small cultivators to produce the remainder. They advance money to these cultivators, but require the cane to be grown according to their instructions : they decide on the variety, manuring and cultivation and see that these are properly done. The arrangement has many advantages.

The presence of this skilled and intelligent planting community is a great advantage to the research workers : constructive criticism is possible and useful results can speedily be put into practice.

Sabour.

(Visited February 21st and 22nd, 1937.)

The Sabour Institute was started as an Agricultural College, but it is now restricted to agricultural investigations.

Investigations on rice.

Bihar has some 15 million acres under rice and produces about one-fifth of the total Indian rice crop. It is proposed to set up an advisory and research organisation similar to that adopted for cotton in Madras ; a paddy specialist is to be placed at the Central Rice Research Station, with competent assistants in each of the four main rice tracts : North Bihar, South Bihar, Chota Nagpur and Orissa.

Meanwhile a comprehensive programme of research has been drawn up.

Sabour Paddy investigations.

GRANT : Rs. 2,02,140 spread over 5 years.

Rice Specialist : Mr. M. M. Alam.

The Rice Research Scheme consists of four parts :—

(1) Studies of the agricultural and botanical characteristics of the 5,000 pure lines of rice now grown here with a view to multiplication of promising varieties.

For purposes of classification Hector's criterion the weight per unit length, *i.e.*, the weight of 1,000 grains divided by the average length of the grain, is used. It is considered to afford a valuable index of the quality and fineness of the grain.

(2) Selection to suit the four different conditions of cultivation in Bihar :—

(*a*) the one crop area ;

(*b*) the irrigated area around Sabour ;

(*c*) the terraced hill area around Chotanagpur ;

(*d*) the rainy area of northern Bihar.

Later on it is hoped to start breeding of new varieties.

(3) Cultivation experiments ; manurial and general agricultural trials on questions such as spacings, number of seedling per hole, age

of seedling at transplanting, etc. The varieties studied include the Aus (autumn), "Aman" (winter), Dalna (summer).

(4) Certain physiological experiments. The water requirements of rice is about 400([1]) on the unmanured plots, but is reduced by fertilizers or farmyard manure. It reaches a maximum at the flowering period.

As with sugarcane shortening the day by cutting off some of the hours of sunlight expedites flowering even of the so-called time fixed varieties ; even a small reduction, *e.g.*, of 2 hours per day, has a considerable effect. Mr. Alam proposes to use this device for breeding new varieties. On the other hand, lengthening the day by artificial light causes only a small delay in flowering.

Dr. Mirchandani discussed the chemical investigations with me : it consists of two parts : a detailed study of the effect of cultivation and fertilizers on yield ; and investigations on the composition of rice. The fertilizer and cultivation problems should I consider be studied seriously and adequately. Work on composition should be undertaken only if needed to round off some larger investigation on the value of rice in human nutrition.

Mineral composition of pasture plants.

GRANT : Rs. 25,470 spread over 5 years.

This is part of a general scheme for the study of pasture plants. The samples are supplied by forest officers who, however, do not send samples of soil as well. This, however, should be done in future, now that the preliminary analyses have been made. The mineral composition of herbage is related to the soil conditions, and it is more useful to discover the general nature of this relationship than to a mass data in regard to casual samples of herbage. Samples taken from Government farms can of course be studied more completely, because something is already known of the soil.

The Fruit Research Scheme.

The fruit research scheme at Sabour serves not only Bihar but the United Provinces also, a commendable and economical arrangement. It is concerned largely with the three fruits most important in the plains : mangoes, leitchis and papayas. The staff includes Dr. P. K. Sen, who at the time of my visit was still at East Malling completing a period of two years study ; Mr. R. Zarbakht Khan in succession to Mr. K. C. Naik ; with Miss Rajul Shah as Assistant.

Mangoes.—Some 50 varieties of mangoes have been planted from different parts of India and methods of propagation are being studied. Inarching is the old method, and the one almost universally practised, but it is costly. The usual method is to use one year old seedlings ; a modification has, however, been devised that can be carried out with seedlings only 2—4 months old. So long as the stocks are seedlings, however, the resulting trees are bound to be variable no matter how the grafting is done. Hitherto propagation by cutting,

([1]) *I.e.*, 400 parts of water are transpired per unit of dry matter formed. The relationship is not causal, so that the figure has no absolute value.

layering and budding have failed but it is desirable to persevere with vegetative reproduction of stocks which would at any rate give uniform trees. Growth promoting substances such as indolyl acetic acid are now obtainable which cause cuttings to send out rootlets ; the effect of some of these might be examined.

A considerable amount of work on cultivation is proposed including a comparison of clean culture with grass culture. Mangoes appear to show some periodicity in bearing, giving alternately larger and smaller yields in successive seasons. Various methods will be tried for dealing with this property, including smudging, *i.e.*, lighting a smouldering fire under each tree—a device which in the Phillippine Islands is stated to force the dormant buds into breaking.

Papayas.—Papaya trees are extremely variable and it is difficult to make reliable field trials with them. It is proposed to repeat Dr. Hofmeyer's experiments on the continued intercrossing of plants raised from seed of the same tree, so as to see if some steady condition can be attained. As at Poona, attempts are made to find some correlation between the external characters and the sex of the young plant.

Other crops.

A considerable amount of work on other crops is being done at Sabour.

Sunn hemp.—Hitherto mass selection has been adopted in attempting to improve sunn hemp. Mr. T. C. N. Singh is working on single line methods fertilizing the plants by means of bees washed in formalin so as to kill any foreign pollen. [See p. 185 (Poona)].

Barley.—Samples of barley selected by Mr. Singh have been submitted to the Institute of Brewing for report.

Tube wells.—Some interesting work is being done here on this subject by the Agricultural Engineer, Mr. H. W. Stewart.

Improved implements.

I heard good accounts of the successful demonstration work done by Mr. A. P. Cliff who took improved implements round in a bullock cart among the cultivators and would on the spot arrange a demonstration unyoking the bullocks from the cart for the purpose.

Patna Farm.

Economics of irrigation from tube wells.—A considerable area in Bihar is successfully irrigated from tube wells, and it would be possible to irrigate further areas if this should prove economical. An application has been put in for a grant of Rs. 78,680 spread over a period of 5 years, for investigations on the costs of the water at pumphead and the costs of its distribution, the best ways of stilizing

it and the measurement of the losses. The subject is important and the application should be favourably considered in relation to the irrigation investigations as a whole.

ORISSA.

Cuttack Rice Research Station.

(Visited March 10th, 1937.)

The chief work here is the collection of strains and selection from these of desirable varieties. Three kinds of rice are important in this region :—

(1) Daljua or summer rice—a bore variety ;

(2) an Aus variety, Beali ;

(3) an Aman variety, Saradh ;

these being respectively early, mid—and late season. Several different varieties are needed to satisfy the different types of physical and economic conditions. A considerable area in this part of Orissa lies low and is flooded during the monsoon. The paddy must tolerate submergence for about 15 days and the roots and stems must be strong enough to withstand the current of water. The flood water subsidies by the end of October, but the depressions remain full of water. As this evaporates or soaks away, boro rice is planted. But the supply of seed is never plentiful, and it becomes wholly insufficient in years of heavy flood when the area under boro greatly increases. An attempt therefore is made to find earlier Aus and Aman varieties so that in an emergency they could be used to supplement the boro. Near the coast, however, is a belt liable in the summertime to inundation from the sea, consequently rices planted here must tolerate salinity.

Another problem arises from the circumstance that the food supply of the poor cultivators tends to be exhausted by July, owing to the smallness of their holdings. The earliest rice, sown in December and harvested in April or May, is all used up and the Aus, which is broadcasted in May or June at the break of the monsoon, is not ready until September. Search is being made for a variety which could be sown about the end of May and harvested about the end of August.

In addition to the selection work there are also manurial trials, which, however, are not well designed and should be replaced by a better series.

Ravenshaw College. Investigations on Water-hyacinth (Eichonnia crassipes).

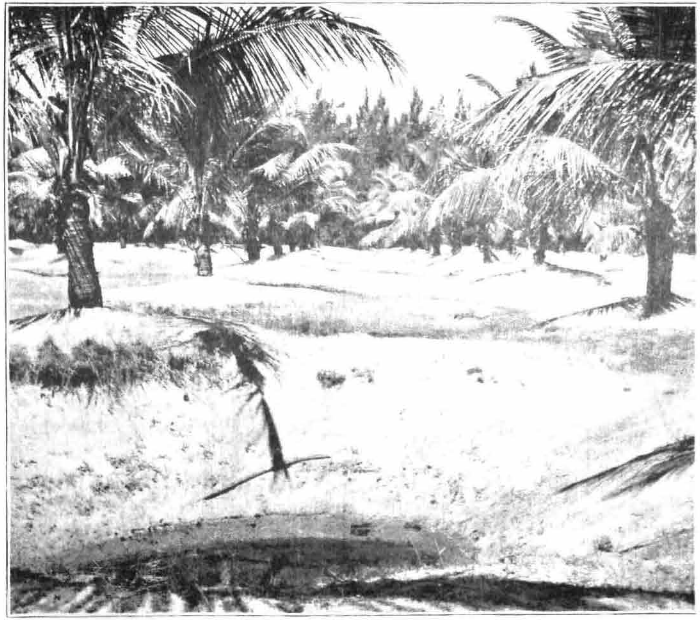
These investigations are now completed : they were in charge of Professor P. Parija and a grant of Rs. 4,040 has been made. Professor Parija showed that this plant propagates from seed : he studied its method of growth and floating up ; and explained why

it reappears in tanks which have been cleared. Further, he demonstrated that there are critical periods in the year when a single re-clearance of a tank prevents the weed coming back.

Water hyacinth, and the equally harmful lantana, are both foreign plants, introduced by well meaning and enthusiastic gardeners, and have now become serious scourges. They rank with cactus in Australia and gorse in New Zealand as standing warnings against the introduction of new plants into the country excepting after most searching test in some completed isolated area.

Cocoanut Plantation, Puri.

A cocoanut plantation has been set up on the light sand-belt running along the sea coast ; other fruits are being grown also. The results seem quite promising and suggest the possibility of putting to good use much land now lying waste.



Reclaiming the sand.

(PURI—ORISSA.)

CENTRAL PROVINCES.

The sown area of the Central Provinces is fairly evenly divided between rice, juar, cotton, wheat and linseed added together, and all other crops ; the total sown area is about 25 million acres and each of these crops or groups adds up to about 4 or 5 million acres. The distinctive features are the large area under linseed, the high proportion under cotton in Berar, the increasing area under ground nuts in rotation with cotton, and the small areas of bajra and sugar cane.

Nagpur Agricultural College.

(Visited January 7th and 8th, 1937.)

In several of the Departments work is going on which bears closely on the schemes fostered by the Council.

Chemistry Department.—The work is in charge of Professor A. J. Bal. He proposes to complete the survey of the rice soils of the region which was begun by Dr. Mukherji, of which about two-thirds is already done. He is also making analyses of vegetables : in this I suggest that the co-operation of Dr. Aykroyd be secured.

Dr. Bal has repeated Dr. Dhar's experiments on photo nitrification, but is unable to confirm his results.

The laboratories are sufficiently equipped and the work is on sound lines.

The Botanical Department.—Professor K. P. Shrivastava.

Experiments are in progress on the improvement of wheat, gram and other crops. Rust resistant varieties of wheat are sought for the northern parts of the Central Provinces and early ripening varieties for the plains of the south. The work appears to be well done.

Mycological Department.—Mr. J. E. Dastur is studying root diseases of rice and wheat, various wilts, etc.

Some interesting cotton experiments are carried out by Mr. D. N. Mehta, Economic Botanist for cotton and connected crops, and some good marketing investigations by R. H. Hill ; these, however, lie outside the province of this report.

Oil Seeds.

A scheme for Research on Oil Seeds in the Central Provinces has been sanctioned, the grant being Rs. 52,280 to be spread over 5 years. The work had not been begun at the time of my visit.

It will be confined to four crops : linseed, sesame or til, safflower, and *niger (Ramtil)*. *Of these linseed is the most important in the* Central Provinces, occupying an area of nearly 1 million acres, this being much larger than in any other province : indeed the total production here is about one half that of all India. The yields, however,

are low : only about 235 lb. per acre while in the United Provinces and in Bihar and Orissa they are more like 500 lb. per acre. Oil seed schemes are in hand in other Provinces : the distinguishing feature of this one is that the experimental crops will be grown in black soils which are said to produce about a quarter of the whole Indian crop, and a valued trade type, while in other schemes the soils are different : for the past 30 years, for instance, experiments have been made on the Indo-Gangetic Plain.

Sesame comes next in importance with about 338,000 acres : the Central Provinces being the second largest grower ; the largest is Madras.

As at the other centres, the work will consist in the search for varieties giving higher yield and better quality of oil. Linseed varieties will be sought resistant to rust.

Sunn Hemp.

A Sunn hemp Scheme has also been sanctioned, the grant being Rs. 10,600 to run over 5 years : this work is not started. The programme will be in general similar to that in Madras, Bombay, Bihar and Orissa.

In view of the good laboratory accommodation available at Nagpur, and the standard of the scientific work done there, one may expect useful results from all these schemes.

Fruit—Oranges (Santra or loose skinned type).

A grant of Rs. 71,160 spread over five years was made in June 1936 for investigations into the cultivation of the Nagpur " Santra " loose skinned oranges. These are now known all over India and budded plants are in considerable demand ; but no guaranteed supply is available. It is proposed to study root stocks and their effect on the yield and quality of fruit, the vegetative reproduction of the trees, the irrigation, manuring, pruning, and general management. The work certainly needs doing, and Nagpur is a suitable place.

Gangai pest Scheme.

Entomological Department.—Rai Sahib G. R. Dutt, the Government Entomologist, is investigating the Gangai pest of rice, caused by *Pachydiplosis oryzae,* a small insect that gets into the shoot and eats part of it so that no ear forms. Considerable damage is done in some circumstances. The programme of investigation includes the search for alternate hosts among the grasses growing near the paddy fields with the purpose of finding how the insect survives from one season to another ; particular watch will be kept on wild grasses and Kodon (*Paspalum scrobiculatum*) which suffers in a similar way, presumably from the same pest.

The incidence of the attack on plots sown earlier than usual, the effect of fertilizers, and the natural enemies and parasites will also be studied.

The grant sanctioned is Rs. 5,924 to be spread over a period of two years.

The field work is to be done at Raipur. The work seems to be well begun and Mr. Dutt shows much ingenuity in overcoming the practical difficulties.

Raipur Rice Station.

(Visited January 9th, 1937.)

GRANT : Rs. 91,927 for a period of 5 years.

The work was started in 1932 as part of the co-ordinated scheme of rice investigations carried out at Nagina, Coimbatore and other centres ; the Raipur programme differs in that more emphasis is laid on soil analysis and on fertilizer requirements. Dr. Mukerjee was in charge until he was appointed agricultural chemist to the United Provinces.

The Botanist, Mr. B. B. Dave has made a collection of about 700 types of rice and has classified nearly 400 fixed strains.

Part of his work consists in finding some way of dealing with wild rice, a weed which reduces both yield and value of the crop on the light soils where the rice is broadcasted ; the problem does not arise on heavy soils where it is transplanted. This wild rice has a green stem like the ordinary varieties and so is indistinguishable from them and cannot be weeded out. Mr. Dave is therefore breeding a rice with a purple stem which the cultivator can easily distinguish from the wild rice. A variety possessing purple auricles was crossed with a commercially desirable variety and the offspring while retaining these good qualities had also the purple colour.

Mr. Dave is a capable Botanist and the work is being well done. The field work in connection with the Gangai pest is done here.

Professor Bal is now in charge of the soil work. Reference has already been made to the survey of the Rice Soils. In the manurial experiments nitrogenous fertilizer alone, whether organic or inorganic, had little effect on yield, but phosphate fertilizer gave a substantial increase.

Another problem being studied is the possibility of converting rice husk into useful compost. Much hulling of rice is done in the local mills and considerable quantities of husks are available. They rot extremely slowly in ordinary circumstances, however, and Dr. Bal is studying methods of hastening the decomposition.

INDORE.

Indore Institute of Plant Industry.

(Visited January 12th and 13th, 1937.)

The Institute of Plant Industry at Indore was set up in 1924 through the joint action of a number of bodies which united to form a society incorporated under the rules of the Holkar State. The

principal supporters are the Indian Central Cotton Committee who paid for the buildings, land and equipment and who contribute liberally to the maintenance : in addition some 27 States make annual grants.

The first idea had been to provide a farm for the Agricultural Adviser to the States in Central India, Mr. Bernard Coventry, but the scope was soon widened, and the main work now is fundamental research on the breeding and cultivation of cotton, though other crops are also studied.

The first Director was Mr. (now Sir) A. Howard, who with his late wife were lent by the Government of India to the Institute in 1924. The general principle underlying the Howards' administration was that there should be no fragmentation of scientific work into departments, but that the staff should take the crop as their unit, studying it in relation to the field and the village. During this period the land was brought into good condition, erosion was stopped, the pernicious weed Kans was brought under control, and provision was made for supplies of organic manure.

In 1931 Mr. Keith Jackson succeeded as Director and arranged for studies of the soils in relation to crop varieties ; he was followed in 1936 by the present Director, Mr. T. R. Low.

The work on cotton and food crops.

The main work, as already stated, in on cotton and at the time of my visit this was in the hands of Mr. C. M. Hutchinson who has since left for the West Indies. It was among the best work I saw in India. Mr. Hutchinson has not only surveyed the existing varieties and bred new sorts from them, but he has studied in great detail the principles on which selection should be done. Usually selection is mainly empirical: these investigations are opening the way to a more definite basis. Work of this quality is rare and it is a great misfortune that it has been terminated.

He is succeeded by Mr. Ramiah, paddy specialist from Coimbatore, who has a good record of useful work.

There is also some useful selection work on juar. Mr. Hutchinson has adopted a "compartment" method of mass selection which seems promising.

The Chemical Section.

This is under Mr. Y. D. Wad and is concerned with the study of the effect of environmental conditions on the growth of the cotton crop he is also continuing the work on composts begun by the Howards. His programme is very extensive and I recommend that it should be much compacted and restricted to two items:—

(1) The influence of cultivation and manuring on the moisture and nitrate content of the soil and on the growth and character of the cotton plant.

(2) The manurial value of compost in comparison with cattle manure, green manure and sulphate of ammonia.

The work on Composts.

The best-known work of the Howards' at Indore was that on the making of compost from waste vegetable matter. His successor, F. Keith Jackson, gave a new turn to the subject by showing how to bring in habitation wastes and human excreta and in consequence made it of sanitary as well as agricultural importance. (1) This two-fold value is now widely recognised: the Provincial Departments have become definitely compost-minded; and in every village I visited, where rural uplift has begun, I was proudly shown as its first fruits the trenches dug to receive the wastes and ordure that otherwise lie about in the village street, a menace to health and comfort. Even if the compost had only small fertilizer value, great efforts to bring it into use would still be worth while for the sake of keeping the village clean.

The making of compost appeared in the programme of most of the experimental farms I visited. A variety of methods are being tried, the Indore methods, especially the later one, Dr. Fowler's, Professor Subramanayan's at Bangalore, and several others.

Certain general results are well established. In making compost the initial difficulty is the loss of moisture from the heap, which if not corrected would soon bring the whole process to a standstill. This is overcome by adding soil which retains sufficient moisture for completion of the process: for convenience urine earth from under the cattle is used.

There must also be some relation between the soft and hard woody material in the heap: more soft leafy vegetation must be added if much hard material is present.

Composting affords a satisfactory way of disposing of household wastes and excrements. It is, however, not necessary to use either these or farmyard manure: the young leafy material provides sufficient carbonaceous and nitrogenous matter to promote satisfactory decomposition.

Adequate supplies of air and water are necessary.

The nitrogen in the compost at the end of the process may be as-much-as 1 per cent. in farm compost and 1.5 per cent in habitation wastes. Much nitrogen is lost during the process especially from habitation wastes, and no way of avoiding this has been discovered.

The field experiments with compost are few and inadequate. It is everywhere assumed that compost is useful but few of the officers could point to any evidence. Recent Indore experiments suggest that it acts well on irrigated land but is less effective on the unirrigated black cotton soil unless it can be worked into the subsoil. Proper tests should be made so that the agricultural officers may know under what conditions compost gives its best results.

In any case the cultivators should be encouraged if only on purely sanitary grounds to make compost of their wastes and village sweepings and to put it on the land.

---

(1) See Bull. 1, 1934, Inst. of Plant Industry, Indore (F. Keith Jackson and Y. D. Wad).

BOMBAY PRESIDENCY.

Bombay is the second largest of the Provinces, its total area being nearly 79 million acres, but nearly 20 million acres are classed as "not available for cultivation" this being a larger proportion than in any except the North West Frontier Province. Of the net area sown (32.8 million acres) just over 5 million acres are irrigated, mostly by Government canals. The cropping is characterised by the large proportion of juar or Cholam as it is here called, and of bajri, but there are also moderately large areas of wheat, rice, oil seeds, and fodder crops (2.6 million acres). Cotton is the most important cash crop, sugar cane being but little grown.

The city of Bombay is well provided with scientific institutes and while there I had the opportunity of visiting both the Royal Institute of Science and the Cotton Research laboratories at Matunga where some admirable work is being done (page 7). One of the Council's schemes was located at the former institution: the work is complete but as I had the opportunity of discussing it with the author I shall here describe it.

Rice Physiology.

Dr. R. H. Dastur.

Dr. Dastur's physiological studies of rice began in 1927 in the Botanical Department of the Royal Institute of Science, Bombay, and went on for several years. The work consisted in the study of osmotic and suction pressures of the roots and leaves of the rice seedlings at different stages of growth and their relation to the concentration of salt solutions in which they are immersed. There was evidence that ammonium ions were absorbed in preference to the nitrate ions in the early stages of growth but not at the later stages, and it was suggested that the mixture of ammoniacal and nitrate nitrogen might be a better source of nitrogen to the plant in the field than either taken separately. Field experiments, however, have shown that this is not so: this is of course no reflection on the work; it is well known that soil and the climatic conditions play an important part in determining the relations between the plant nutrient and plant growth. The value of the work lies in the help it gives to students and teachers, and I suggest that a connected account of the physiology of the rice plant should be prepared, if possible by Dr. Dastur himself, so that they may be able to make use of it for teaching purposes.

The Poona investigations.

(Visited December 5th—9th, 1936.)

The most important centre of agricultural research in the Presidency is Poona, where the Agricultural College, the Meteorological Office and the Ganesh Khind fruit farm are placed. Out in the Province, however, there are some well equipped and well staffed experimental farms.

The Council's schemes at Poona are concerned with plant diseases, fruit and agricultural meteorology.

The Poona Agricultural College.

This College was founded in 1909 and has become one of the most important in India both as a teaching and as a research centre.

Several of the Council's schemes are directly or indirectly associated with it.

Plant disease and pests.

Virus disease of plants.

(Visited December 5th—9th, 1936.)

GRANT: Rs. 80,474 spread over 5 years.

The work is in charge of Professor B. A. Uppal, (Plant Pathology Section) and has only recently started.

As a preliminary step Dr. Uppal was sent on deputation to the more important plant pathology laboratories in England and America, to study the methods in use and the results obtained there. Six months were spent at Rothamsted where he favourably impressed the staff by his ability, and the remainder of the time was spent in seeing the best of the work done in other laboratories in England and America. He begins his work, therefore, well informed as to what has been done elsewhere, and he is to be provided with a suitable staff and satisfactory appliances including a good glass-house. He will make a general survey of virus diseases in India, giving particular attention to those of chillies, cardamoms and Bhendi (*Hibiscus esculentus*). His programme seems to be quite sound and promising.

Besides this work for the Imperial Council of Agricultural Research Dr. Uppal has a number of other schemes in hand, including work on cotton wilt for the Indian Central Cotton Committee; on linseed for the Sassoon David fund; some 10 or 12 departmental problems; in addition to College lectures and advisory work which takes him away for many days during the year. It is of course impossible for one man adequately to take charge of so many things, and the Council and College authorities should consider whether he could not be relieved of all but one or two items of his heavy programme so that he can do justice both to the work and himself.

The Parasite "Striga" of the Juar crop.

GRANT: Rs. 27,060 spread over 5 years.

The work is only just beginning and Professor L. S. S. Kumar is in charge.

The parasitic plant "Striga" causes considerable loss in certain districts to growers of Juar; it is a flowering plant producing a large number of minute seeds and once established its eradication seems

to be almost impossible. Fortunately some varieties of juar are less susceptible than others and it is proposed to select these and, if necessary, breed from them so as to obtain a resistant variety possessing also other desirable characters. The Programme of work includes studies of the effects of cultivation and rotation. The work should be done on land known to be infested, as it is always difficult to ensure the maintenance of natural conditions on artificially infested land. Various physiological, histological and cytological studies are also proposed but these should be strictly subordinated to the more practical experiments: parasitism as a scientific study is much more appropriate to a University than to an experimental station.

A similar, but not identical, pest affects millets in South Africa and has been successfully dealt with by finding resistant varieties. There is, therefore, hope that the problem can be solved here also.

Various other investigations at the Agricultural College are closely allied to some of the Council's schemes.

Agricultural-Economics Section.—Mr. V. V Gadgil.

Costs of production of individual crops are studied in selected villages in the Poona—Sholapur and Nasik districts. Studies have also been made of the economy of the farm as a whole. Some of the results have already been published as bulletins of the Department of Agriculture. A considerable amount of trouble is taken to obtain the necessary basic figures and the work seemed to be well done.

Entomology Section.—Mr. Jhaveri.

The bionomics of various insects are studied, including Chillie Thrips (*Scirtothrips dorsalis*) and a beetle-vine bug (*Disphinctus measurum*) work is also done on the control of cabbage aphis.

Plant Pathology Section.—Dr. B. A. Uppal.

Numerous investigations have been made here, including the well-known work of Dr. Burns and Patwardhan which led to the control of downy mildew in grapes by spraying with Bordeaux mixture. Another mildew, the powdery mildew of grapes, cannot yet be controlled, it is now being studied.

Chemistry Section.—Rao Bahadur D. L. Sahasrabuddhe (now retired).

The work of this section has included studies of nitrogen changes in rice soils: some fixation is stated to occur.

The intake of plant mutrients by wheat and sunn hemp, and the changes during the ripening and storage of fruits and the composition of the proteins of cereals and legumes, have also been studied.

Agricultural-Engineering Sections.

Experiments are made on the threshing and winnowing of gram, on the improvement of cultivating implements, and of the bullock cart, especially the fitting of ball bearings, which is within the means of the cultivator, while rubber tyres in general are not.

Some interesting soil erosion observation studies are made here and also in certain areas liable to erosion.

The Ganeshkhind Fruit Experimental Farm.

COLD STORAGE RESEARCH SCHEME.

This work began in March 1934 and is carried out at the Ganeshkhind Fruit Experimental Farm, Poona, in charge of Dr. G. S. Cheema, with Dr. D. V. Karmarkar and Mr. B. M. Joshi as assistants. The grant is Rs. 17,926 annually for 3 years with Rs. 36,375 non-recurring, making a total of Rs. 90,154.

There appears to be a marked increase in consumption of fruit in India, and in consequence in the Deccan, as in most other parts of India that I visited, there is considerable interest in fruit growing. An increase in fruit production in India would in many ways be a most desirable development : it can come about, however, only if adequate transport and storage facilities are available and this in turn necessitates the development of refrigeration.

Investigations on cold storage of fruit are therefore essential to further extension of fruit growing. They are carried out here with apples, mangoes and other fruits of economic importance, and they are extended also to include seed potatoes, the storage of which during hot weather presents many difficulties in ordinary practice.

The apples were keeping satisfactorily ; those shown to me were unsuitable for export because of their bad colour : some were a dirty red, others dark green but with many spots on them : they were much less attractive than the pleasing looking apples of the Quetta region. This, however, appeared to be more a question of variety than of storage, and in any case it was said to cause no difficulty in practice, since the local market raised no objection to the colour.

Considerable work is being done on the storage of the mango, and it is claimed that shipments to England are now possible, but much work remains to be done both in India and in England before an export trade can be started. In the meantime the area under mangoes appears to be extending in the presidency, presumably in the hope of an increasing export trade. Even if this failed to eventuate, however, an increased consumption in the Indian cities would still be desirable.

Suitable conditions are being studied for the storage of seed potatoes ; at present it appears that 40°F is a suitable temperature.

Other investigations not coming under the Council include crown grafting of mangoes, studies of two abundant and popular fruits, guava and ziziphus, and of several higher grade fruits : grape fruit, figs, pomegranate : also of cashew nuts and vegetables including the very popular brinjals and chillies.

In view of the interest being taken in fruit growing and the difficulty of ensuring that stocks and varieties supplied shall be true to name, it is proposed to establish a register of nurserymen whose stocks have been properly examined and can be vouched for by the Department.

The Station is well equipped for its work and suitable for fruit and vegetable growing.

The College also has a Department of Mycology and Entomology and a Horticultural laboratory where among other things fruit preservation is studied.

In view of the importance of increasing the supplies of fruit and vegetables to the towns I consider that the work on cold storage should be continued, and that the possibility of expansion on the production side should be considered.

Improvement of Papaya Breeding.

GRANT : Rs. 6,000 spread over 3 years.

The work is to be done by Professor L. S. S. Kumar and Dr. G. S. Cheema. The original scheme included experiments on cultivation and manuring ; attempts to distinguish the male and female trees at an early age ; studies of the occurrence and inheritance of sex ; and the cytology of the sex forms in the Payapa. The Board limited the investigations to this last problem.

There would be considerable advantages in being able to detect female trees at an early age so as to ensure that adequate numbers were planted, and only the necessary minimum of males. Drs. Kumar and Cheema are well equipped for finding some solution of the problem, if on present knowledge this is possible.

Vitamin Content of Mangoes. (Completed Scheme.)

This was supplementary to the scheme for experimental shipments of mangoes from Bombay to London. Analyses made by Miss Edith O. V. Perry and Dr. S. S. Zilva showed that mangoes were rich in vitamin C, contained moderate quantities of vitamin A, but no significant amount of vitamin D. If the export trade in mangoes ever reached important dimensions, this information might have value for propaganda ; in the meantime it is useful for the Indian medical authorities.

Agricultural Meteorology : Meteorological Office, Poona.

These investigations were begun in 1932 in charge of Dr. L. A. Ramdas, the Agricultural Meteorologist, and R. J. Kalamkar, Statistician.

The annual grant is Rs. 20,470 : the non-recurring grant is Rs. 5,600 and the total sum allotted is Rs. 1,07,950. The work is divided into two sections : exeprimental and statistical ; the experimental part being done on the College farm where an Agricultural Meteorological observatory has been set up, while the statistical part is done at the office.

The general purpose is to work out two balance sheets :

(1) a thermal balance sheet showing what becomes of the radiant energy received from the sun ;

(2) a water balance sheet for the earth's surface, showing the amount received at the surface from the rain and the amounts lost by evaporation, transpiration and percolation.

The Agricultural Meteorological observatory is well equipped for an unusally wide range of observations dealing with the soil, the air, the fate of the rain water, and effect of the growing plant on the climatic conditions around it.

The total radiation from the sun and sky on unit area of a horizontal surface, a fundamental element in meteorological and biological research, is measured with a solarigraph. Another instrument has been devised to record the heat lost through convection by the soil surface in the daytime. Measurements of (1) the albedo (or reflection) coefficient of different soils, (2) the heat radiated from the soil surface, (3) the heat returned to the surface by radiation from water vapour in the atmosphere, and (4) the heat exchanged by conduction within the soil itself between the surface and the lower layers, provide further information regarding the heat balance at the surface of the ground.

Detailed studies of the soil temperature at different depths are made. As is well-known, the surface of the soil becomes very hot in summer : at the observatory it has risen to 75°C in May ; during the *night it is much cooler. A little below the surface the daily variation* of temperature is much less, and at a depth of one foot there is no difference between day and night temperatures : the roots of plants, therefore, live at much more uniform daily temperatures than do the leaves and stems. The seasonal changes of temperature, however, are felt in the soil even to a depth of 6 feet, the greatest depth at which observations are taken, though the difference between the hot and the cold seasons is much less than at surface. The temperature of the upper layers of the soil, however, depends very much on the colour of a bare soil and on the covering of a covered soil : a light coloured soil being much cooler at the surface than a darker soil.

Attempts are being made to devise an apparatus for the measurement *in situ* of the soil moisture. A porous pot candle and gauge are used and the results are checked by direct determinations. These attempts should be continued : a trustworthy and easily worked method would be of great assistance in irrigation and dry farming investigations.

Much attention is given to the climate within the growing crop —the local or microclimate—as compared to the general climate round about it. There is no simple relation between the microclimate within the crop and climate outside, but there are certain general differences. At the maximum period (afternoon) the temperature within the crop is distinctly lower than the temperature outside, especially at the surface of the soil : for the densely growing sugar cane the difference there may be as much as 10°C, though it is much less at 4 ft. above the surface : for the more open growing jowar the differences are of course less. The microclimates within the different crops are closely correlated at minimum temperatures but not at maximum temperatures : the difference is attributed to turbulence.

Measurements of the variation of air movements with the help of a sensitive anemometer, both in the open and inside crops, are being arranged ; when such additional information is obtained it may

be found possible to express the climate of the crop more fully in terms of the climate of the open. During the day the air is warmest just at the surface of the ground and cooler as one rises to 3 or 6 inches, while the stem of the sugar cane is coolest at the surface of the soil, a little warmer at 3 inches and still warmer at 6 inches height : but it is always cooler than the air though the difference in temperature diminishes rapidly from the surface to the 6 inch height. At night, on the other hand, the stem is warmer than the air, though the difference is not great.

During calm weather the minimum air temperature is not on the surface of the soil but about one foot above, indicating that the cooling is not from the soil but from the air itself.

Evaporation of water, an extremely important factor in Indian agriculture, is measured direct from a free water surface. A much simpler device, however, is said to give sufficiently good results for ordinary farm purposes. The rainfall here averages about 27 inches yearly but the evaporation from a water surface exceeds 100. The soil of course loses less than this and fortunately even the water evaporated from the soil is not all permanently lost. Part of the water evaporated during the day falls back as dew, a long-known source of water for plants : " there went up a mist from the earth, and watered the whole face of the ground ". During the very dry period, when the surface layer of the soil is so far dessicated as to contain only hygroscopic moisture, the soil absorbs from the air during the night practically all the moisture it lost during the day, so that the net loss is practically *nil*.

The subject being new a good deal of attention is necessarily devoted to the comparison of various types of instruments to find which give the most accurate readings or which are in practice the most useful for the purpose.

A beginning was made some years ago with the issue of frost warnings to the grape growers of Nasik, and arrangements have more recently been made, as an experimental measure, to issue cold wave warnings from the forecasting section at Poona to those provinces in India which are liable to the incidence of frost. Experiments on prevention of frost damage have been begun at Nasik.

A provisional scheme for issuing warnings of heavy and untimely rainfall to the various districts of the Bombay Presidency has also been drawn up.

The section at Poona has been co-operating with the officers in charge of other Research Scheme inaugurated by the Imperial Council of Agricultural Research, *e.g.*, the sugar cane, dry farming, Rust and Locust research schemes, by advising them on the meteorological aspects of their work. The section also assists agricultural departments and institutions in India by training agricultural assistants, and by advising in regard to meteorological equipment, etc.

The statistical work is done by Dr. R. J. Kalamkar. He has applied the methods of R. A. Fisher for studying the yields of wheat in the long continued experiments (29 years) at Cawnpore, and finds no evidence of soil deterioration, though other slow changes appear

to have taken place. Continued high yields were obtained by artificial fertilizers without the use of organic matter, and the annual variation in yield was least where nitrogen was supplied. The effect of rainfall on the cotton yields at Akola, in the Berar cotton tract (28 years' records) was also studied by Fisher's methods. The cotton is sown early in June : rainfall appears to have an adverse effect if it comes in late May, *i.e.*, just before sowing :—a beneficial effect if it comes soon after June : and an adverse effect in July, August, and early October : the significance of these effects, however, is not very marked. On the other hand high maximum temperature in May tends to increase the yields (this may explain the rainfall effect) by causing the black cotton soil to become more friable.

Precise records of the development of the wheat crop are taken at periodic intervals, on lines similar to those taken at Rothamsted, Woburn and elsewhere in England.

The Director, Dr. C. W. B. Normand, was absent on leave at the time of my visit but I was shown over the office by the acting Director, Dr. S. K. Banerji.

Up to the present the cost of the Agricultural Meteorological scheme has been defrayed entirely by the Council. In the next five year period it is proposed that the cost be shared in equal parts by the Government, and thereafter that the Government should take over the whole of the cost. This arrangement seems to be satisfactory : the need for investigations in agricultural meteorology is beyond question and Poona is the obvious place for the work. It should now be on a permanent basis.

Some problem may always emerge, however, that deserves fuller investigation and necessitates temporary additional staff. The Council could then consider the possibility of making a specific grant. The fact that meteorological observations are being made in association with the growing crops gives a good opportunity for some interesting work on plant physiology of which the Agricultural College might wish to take advantage, subject to the approval of the Meteorological Department. It cannot be claimed that immediate results of practical importance would follow, and any grant which the Imperial Council might give would be in the same class as grants to Universities.

Other schemes.

SUNN HEMP.

GRANT : Rs. 6,000 spread over 3 years.

The work is done in the Rajapur, Devgad and Chiplun districts, the parts of the Bombay Presidency where the best quality sunn hemp is grown. The region is hilly, and the soil rocky ; sunn hemp is the only cash crop. The purpose of the investigation is to study the possibility of increasing the present area under the crop ; to increase the yield of fibre and to improve its quality.

Tractor cultivation. Burmah Shell Company.

Experiments carried on from 1930 to 1935 to find out how far tractor cultivation would be possible in India showed that it was useful for breaking up new land, eradicating some of the deep rooting weeds, and for other special purposes.

Padegaon Sugar Cane Investigation.

(Visited December 8th and 9th, 1936.)

Grant Rs. 3,86,402 spread over 5 years. A further grant is made by the Bombay Government bringing the total for the five years to Rs. 5,15,686.

Bombay Presidency is not a great sugar producing province but the Padegaon experiments are in some respects, especially on the manurial side, more complete than most others, the nitrogen gradient and the uptake of nutrients being especially studied.

The work began in 1932 and the staff includes the agriculturist, Rao Sahib B. P. Vagholkar, the crop physiologist, Dr. R. D. Rege, and the Soil Physicist, Dr. J. K. Basu.

Like some of the other stations, this was not selected for the purpose of agricultural research. The buildings were put up by the P. W. D. for construction purposes, and when they were no longer needed they were acquired by the Agricultural Department, along with the necessary land. From the workers' point of view the Station is malarial and somewhat lonely. Padegaon lies on the east side of the Western Ghats, on the Nira river irrigation systems, some 50 miles south-east of Poona from which it is about 2½ hours journey by rail or by car. It differs in many respects from the stations described in the preceding sections—Karnal and those in the United Provinces. The climate is hotter and drier so that far more waterings are needed—some 37 given at 10 day intervals instead of 3 or 4 ; and a total quantity 95 inches appear to be the optimum dose of water. The cultivator uses even more water : up to 130 inches.

The work differs from that of other Stations in that it concentrates mainly on the effects of soil conditions and water supply on the growth of sugar cane.

Although the work on selection is less prominent than the soil and physiological investigations it goes on steadily. Unlike Shahjahanpur where only medium canes are grown, this Station grows mainly thick canes for the factory, rather than thin and medium canes that can be crushed in the village mill and used for making gur. At present the best of these is Co. 419 : it has a low proportion of leaf to stem, hence its wastage is small, and it grows so rapidly that it speedily passes the stage at which the borer can attack it, so it escapes serious damage.

In spite of its vigorous growth, however, the cultivators do not like it partly because it is too hard for their mills and partly because it flowers freely and the cattle cannot eat the tips ; while the local sort, Pundia, is soft, and suits their mills : also Pundia rarely flowers so that its head consists of leaves which cattle eat readily. But it

gives a lower yield, it is more subject to the borers and more susceptible to seasonal variations than Co. 419.

Other promising varieties are Co. 360, 413, 417 and 421. None of the improved varieties grown here are flowerless. Apart from this character, Ek. 28, a Java seedling, and Hm 320, a Mysore "noble cane", are both well suited to the small cultivator : they are soft and they give better yields than Pundia.

The experiments on the watering of the cane are well-planned and carefully done. Four rates of watering are studied, supplying respectively 70, 95, 120 and 130 inches. Till earthing up time higher waterings have a favourable effect on both varieties, increasing the height, the leaf area, and tillering. The root system on the other hand becomes smaller, less spread out, and weighs less. Flowering is earlier at the higher dose of water than at the lower, presumably because the soil nitrates are more completely washed out. Finally the yield at harvest is less with 130 inches of water than with 95.

The moisture content of the soil in the upper layers is the same for all the rates of watering : but the depth to which the water penetrates differs, this agrees with the results obtained in California. There is no evidence of any upward rise of water by capillary action.

The effect of water shortage is also studied. The plant wilts and some of the rootlets die, but directly water is added new rootlets form and rapid growth takes place, especially in April and May. The result suggests that if water is short it is best not to apply in several small quantities, but to allow the plant to wilt and then to give a good supply as soon as this is available.

Atmospheric humidity appears to be the most important climatic factor determining high yield.

The manurial results show several peculiarities : a remarkable feature is that farmyard manure is ineffective while castor cake, ground-nut cake and sulphate of ammonia all act well. Phosphate is also needed. The results have been further corroborated by bacteriological studies in pots. Molasses do not, as at Shahjahanpur, increase the yield of sugar cane ; instead they decrease it and there is no evidence of benefit to subsequent crops.

Dr. Basu has begun a genetic soil survey in the canal zones of the Bombay Deccan. He has already surveyed the areas served by 3 major canals, the Nira, Right Bank and Godavari Canals, and has traced nine distinct types of soil. A considerable area (about a lakh of acres) of alkaline soil ("Chopan soil" containing much exchangeable sodium), occurs in this region, and experiments are being made to see if the alkalinity and the sodium can be sufficiently reduced by treatment with sulphur or by suitable crop rotation to allow the soils to be cultivated. Some indications of success have been attained, but no process is yet economical: at present certain sequences of crops with slight irrigations improve the soil tilth and lower the exchangeable sodium.

In the Soil Fertility surveys of the Nira and Godavari canals Dr. Basu found that shallower soils were more fertile and less liable to deterioration under cane growing than the deeper ones. Soil

deterioration under cane growing was associated with carbon-nitrogen ratios of 15 or more.

A vast amount of analytical work has been done to follow the uptake of the different mineral constituents and the nitrogen, and many crop measurements have been made on the various growth phenomena such as tillering, growth rate, measures of leaf area, assimilation rates, and rate and type of root growth. These should be discussed with a good botanist.

A useful leguminous wild plant locally called Patada Shevra (*Alysicarpus belgaumensis*) has been found which grows well on the fallows even without water (though of course better with it) producing a great mass of foliage suitable for fodder or green manure.

Now that the first period is over and the preliminary survey of the problems is well advanced, I consider that the programme should be curtailed so that the attention can be concentrated on the highly important problems connected with the water and fertilizer requirements of the cane. Dr. Basu should continue his soil survey provided it does not interfere with the sugar cane investigations.

Both Dr. Rege and Dr. Basu have to make large numbers of computations for their statistical work and they not only have no computor but no machine capable of doing the work ; in consequence a great amount of their time is spent in laborious elementary arithmetic. I consider they should be given either a computor or a machine, preferably both, so that they may be relieved of the mechanical labour involved in all these calculations. I consider the work at the Station very good.

The close connection between the field work, the soil studies and the physiological investigations is admirable, and the fact that the workers confine themselves to sugar can enables them to concentrate on the one problem.

THE DRY FARMING SCHEMES.

In Central India four stations are concerned in dry farming research : Hagari in Madras, Sholapur and Bijapur in the Deccan, and Raichur in Hyderabad : at the two former detailed soil investigations are in progress and the two latter are more concerned with local problems. Hagari has the lightest rainfall but its soil is deeper and less sloping than at the other stations : it also carries a larger range of crops, juar, Italian millet and cotton all being important, while at the other Stations rabi juar is alone grown.

A coherent and unified scheme is in operation at all four stations : the soil examinations are made by the same methods : the "Bombay dry farming method" is to be tested at all four, also the method of alternate cropping and fallow : the water requirements of juar, are studied at Sholapur and of Pennesetum at Hagari.

It was made a condition of the grant that the workers should visit each other so as to discuss their problems and compare results. This arrangement should be carried out.

The adjoining land : dry farming not practised.
Cultivation and sowing wrongly done.

Bombay scheme—Sholapur.

(Visited December 11th, 1936.)

The Western Ghats which run parallel with the west coast intercept a good deal of the rain of the summer monsoon coming from the Arabian sea, and in consequence much of the land in the central part of the Presidency has only the rain of the winter monsoon coming from the Bay of Bengal. Unfortunately this usually takes the form of storms and as much as 4 inches may fall in 2 hours. The rainfall is therefore very variable and unevenly distributed: at Sholapur it has varied from 14 to 48 inches, all falling between July and November: much of it in September or October. Rabi cropping alone is possible, and this is in practice largely confined to juar.

This irregularity in the rainfall constitutes a great problem, and soil erosion is another. The topography of the land lends itself to erosion in these severe rainstorms: there are long undulations down which water can run off, carrying the soil with it.

Experiments were started in October 1933 at Sholapur and at Bijapur to deal with these two problems. The annual grant is Rs. 37,640 and the non-recurring grant Rs. 46,800 making a total of Rs. 2,35,000. Dr. Burns was at first in control but that responsibility now devolves on his successor, Mr. Jenkins. I visited Sholapur but unfortunately could not get to Bijapur.

The Chief Investigator is Mr. N. V. Kanitkar and there is a staff of assistants, of whom Dr. J. A. Daji is in charge of the soil section and Mr. R. B. Gode of the plant section. Mr. G. M. Bapat is Farm Superintendent at Sholapur.

Sholapur is about 140 miles due south east of Poona on a rolling plateau, the altitude of which varies from 1,500 to 2,000 feet.

Soil Erosion.

The cultivator's method of avoiding erosion is to put a large bund at the bottom of the field to hold up the water as it runs away. The bund, however, not infrequently breaks when the flood water rushes down and in consequence both soil and water are lost. A much better plan is to set up a number of low bunds at shorter intervals, but placed so as to ensure the maximum effectiveness.

The experiments at the farm consist mainly in measuring the amount of erosion under three different treatments ; ordinary cultivation and cropping ; cultivation with a special implement that leaves little depressions every few inches on the plots ; and uncultivated fallow, *i.e.*, allowing the land to become covered with weeds. The plots are so arranged that the water running off is collected along with the accompanying silt in a cemented pit where the quantities of both silt and water can be determined. The uncultivated fallow loses least silt and water by running off, and the cropped and cultivated land loses most. This, of course, is well known: the interest of the work lies in the search for some special mode of cultivation which will give results similar to the uncultivated fallow. The plots should at an early date be extended so as to allow more of this work to be done.

There are some experiments on bunding, and these should in my view be extended, since bunding offers a practicable method of reducing erosion to a minimum and ensuring the maximum retention of water. The experiments should be done not only on the experimental farm but on cultivators' land, working if possible across some depression on sloping ground where erosion may be serious : they would not only give useful information to the Staff but serve also as demonstrations to the cultivators. Extended outside experiments of this kind are an indispensable preliminary to any large scale attack on the problem of soil erosion.

Experiments should also be made on the possibility of setting up, in places liable to erosion, protective strips of land covered with some native plant, capable of making good growth and of some value as fodder: such for example as *Cynodon dactylon.* The Forestry Department should be consulted as to the possibility of establishing small plantations as protection in places where the erosion is likely to occur so that an undergrowth may have some chance of developing.

Dry Farming—Sholapur.

The importance of dry farming investigations lies in the fact that nearly one-third of the total area of the Bombay Presidency as now constituted is considered very liable to periodic famines and scarcities due either to the total failure of rain or to unsuitable distribution. Another large area, also estimated at one-third of the total, is liable to famine, though more rarely. The famine tracts include the districts of Ahmednagar, Sholapur, Bijapur in the East Deccan and the eastern portions of Poona, Satara, Belgaum and the Dharwar Districts ; these contain about 25 per cent. of the total population. The other tract less liable to famine contains about 38 per cent. of the total, so that the two together contain about 63 per cent. of the entire population of the Presidency. Irrigation only to a small extent meets the difficulty, but little of the cultivated area in these districts being supplied with water.

The loss of rain water by surface run-off is considerable, and various methods of cultivations are being tried to ascertain their effect on the retention of water by soil. These are made on the two types of soil, the light and the heavy: they are laid out on a good modern plan so that the results can be analysed statistically : determinations of soil moisture and of nitrate content are also made. In addition a large scale test is made of the so-called Bombay method of dry farming, a combination of proper bounding, *i.e.*, small bounds about 9 inches high made by the plough for each half acre: deep ploughing: three or four harrowings after each rain in the early monsoon; thin sowing in wide rows using good seed treated with sulphur to protect against smut: and hoeing between the rows whenever the soil cracks. Not far from Poona I had been shown a good crop of juar produced in this way while the surrounding crops grown in the ordinary had almost failed. All these operations are well known to be effective in dry conditions but there are almost certain to be many ways in which the combination could be improved or cheapened and I recommend that serious attention should be given to this possibility. These experiments also, like those on bunding, should not be confined to the Experimental farm but carried out also on outside holdings so as to

ensure a wider variety of conditions: the effects on soil moisture and on crop yield should be determined.

The experiments should be extended to include the effects of sheep folding, which in the preliminary trials increased the yields.

In the plant section observations are made on the common weeds, one of which "Striga", is a parasitic plant often doing much damage on the peasants' land. The present varieties of juar are all susceptible to its attack, and no resistant variety is yet known. A scheme dealing with Striga has been started at Poona and at an early date some of the field work should be done here. In dry farming conditions weeds are particularly harmful and work on these should be extended.

Another useful line of work is the selection of varieties of juar that are more resistant to drought than those commonly grown now. For the present the selection has to be mainly empirical, there being no sure criterion of drought resistance, except the actual test. As no one can tell where a more resistant plant may turn up the work of selection should not be confined, as at present, to Mohol, but Mr. Gode should be encouraged to study any promising plant he happens to find in the course of his work.

Studies of the root systems of the different varieties should be made on the lines adopted at Padegaon for the sugar cane.

In addition to the field work there is a good deal of pot culture and analytical work which in my view could be curtailed when the present experiments are finished and the results prepared for publication. This part of the work suffers from the small scale on which it is done due to limitations of staff and equipment: the most hopeful direction of further progress is to concentrate on the field experiments, to extend these to cultivators' land outside the farm, and to carry out on the plots estimations of moisture and nitrate content, studies of root development and of weed suppression. Pot experiments and analyses may of course be needed to interpret the field results but they should be regarded as accessories and not as principal subjects. The physiological and chemical studies of the plant can well be left to some larger Institutions, where there is a fuller staff and where the practical problems are less urgent.

The Hyderabad (Deccan) Scheme—Raichur.

(Visited December 12th, 1936.)

This work was begun in December 1933, the average annual grant being Rs. 10,631 and the non-recurring grant Rs. 6,225 making a total for the five years of Rs. 59,380. The technical staff consist of—

(1) the Superintendent, Mr. Shameen Zuhrie,

(2) the Senior Assistant, Mr. P. K. Savanur,

(3) and the Junior Assistant, Mr. Suryanarayan Rao, lent to the Scheme by Agricultural Department.

The work was shown to me by the Director of Agriculture, Mr. Nizam-ud-Din, the Deputy Director, Mr. H. B. Rajdev and the

Chemist, Dr. P. G. Krishna, who though stationed at Hyderabad, keeps touch with the work and makes periodical visits.

Raichur lies in the south of the Nizam's dominions, right in the centre of the Peninsular, 140 miles due S. E. of Sholapur, but it is at a lower level, the altitude of the surrounding country varying from 1,000 to 1,500 ft., and it is in basin of the Kistna river system. A further difference from Sholapur is that there are two rainy seasons, one in June and July from the south west monsoon, the other in September and October from the north east monsoon. The total annual fall, however, is not great and as in all semi-arid regions, it is variable. In general, however, both rabi and kharif crops can be grown, and in consequence the range is fairly wide: juar is the chief food crop, but there is some bajra and pulse: cotton and ground nuts are also grown as cash crops.

As usual in the Deccan there are the two types of soil, the black cotton soil which predominates and in which rabi crops do well and the lighter land ([1]) on which kharif crops are grown.

The field work falls into two divisions:

(1) Comparison of varieties of Juar (Bombay strains), millets (Madras strains) and cotton, to study their suitability to the local conditions.

(2) Cultivation experiments to compare the Bombay dry farming method with the local methods, and to compare continuous cropping with alternate croping and fallowing.

In addition lysimeter readings are taken to show the proportion of rain-water evaporating and percolation; also the run-off of water is recorded: meteorological observations are also made four times during the day between 8 A.M. and 5 P.M. The work on varieties is on the usual lines and calls for no comment. As already pointed out, the search for improved drought resistant plants must be largely empirical and no opportunity should be missed for selecting and further examining any pomising plant that appears on the plots. At present this is no part of the duty of the Staff: in my view they should be encouraged to do it: as in all empirical work there is an element of chance, but experienced observers having so much material under observation might make some new and valuable selection.

Spacing trials of various kinds are made with juar. No manurial trials, however, are made. I consider this should be done and a suitable place would be in connection with the cultivation experiments: the plots should be split into manured and unmanured halves. In the first instance the manure might be compost, made under the supervision of the Chemist and analysed by him.

In 1936 all the field experiments were recast as suggested by the Dry Farming Research Co-ordinating Committee, and with the exception of the comparison of the local with the Bombay dry farming

---

(1) This black soil is heavy, but loose-textured when dry and is then very liable to erosion; it is underlain in the subsoil by nodules of karkar (calcium carbonate). The lighter soil, locally called Chalka, is red and varies from sand to loam; it is estimated to cover about one-third of the area.

methods all plots are now laid out on modern lines approved by the Council's statistician: the validity of the results can now be determined. As at other places, however, the calculations have all to be done by laborious simple arithmetic, there being no calculating machine available, not even a slide rule except one belonging personally to a member of the staff: in consequence much time is spent that could be better employed.

The variations in the soil moisture of these plots are followed closely, some 10 to 15 soil samples being taken daily for the purpose. A considerable mass of data is thus accumulating which should as soon as possible be worked up and submitted to the Council's statistician for examination and comment. It was soon discovered that the plots are by no means uniform, and I saw at Raichur an unusual sight: underlying rock being blasted out so as to increase the area of land available for cultivation. It is possible that these soil irregularities might necessitate some further modification in the design of the experiments, or even the abandonment of the farm, and this question should be settled soon as is practicable.

I recommend here, as at Sholapur, that the work should be carried beyond the confines of the farm, and that some of the cultivation experiments should be made by the staff also on cultivators' land to see how far the same kind of result is obtained. Both experimenters and cultivators would gain. The method adopted in the Nizam's Dominions of giving grants-in-aid to approved cultivators for carrying out specified work would readily allow outside experiments to be done.

HYDERABAD.

(Visited January 4th—6th, 1937.)

Castor Improvement Scheme.—About 1½ million acres of Castor are grown in India of which more than half are in the State of Hyderabad.

The method of cultivation in Hyderabad differs in some details from that in the neighbouring provinces : it is here grown by itself whereas elsewhere, *e.g.*, in Mysore and Madras, it is usually grown with other crops or even simply as an outside dow. The yields are low; for all India the average does not much exceed 300 lb., per acre, and in Hyderabad yields are even lower. Other countries, *e.g.*, Ceylon, Queensland, obtain 1,000 lbs. or more per acre. There seems room therefore for considerable improvement in the crop, and in the method of cultivation.

A collection of varieties, and selection of improved sorts, was started some years ago at Himayatsagar by Mr. Bhide of the Bombay Agricultural Department, who however has now retired. In 1935 the Council made a grant of Rs. 61,050 to be spread over 5 years for continuing the work, and two assistants have been appointed. From

a considerable number of varieties and strains a few have been selected; these are being selfed and multiplied. The aim is a variety with mostly female main spikes, non-dehiscent capsules so that the seed is not easily lost, and small seed of golden colour.

Hyderabad Fruit Scheme.—While many fruit trees can be found in various parts of the Dominions, there is no important fruit growing industry ; indeed fruit is imported from other parts of India. A scheme was therefore submitted to the Council and was accepted for experiment on Custard apples and grapes, and a grant of Rs. 33,160 to be spread over 5 years was sanctioned in 1936. The work is carried on in the fruit gardens adjoining the farm and consists in the first instance in the classification of local varieties, the selection of types and the propagation of improved varieties, especially suited for commercial purposes. A considerable quantity of material is available, as the Custard apple grows wild in this region.

It is too soon to expect results; I can only say that the gardens are well kept and a beginning has been made with the work.

The Science Congress.

While at Hyderabad, I attended Meetings of the Science Congress to hear Professor J. N. Ray's address on the Chemistry of Anti-Malarials and to take part in a discussion on the need for a soil survey for India.

MYSORE STATE.

Indian Institute of Science, Bangalore.

(Visited December 15th, 1936.)

This Institute is now well known throughout the scientific world as a busy centre of scientific research. The very impressive Physics Department is under Sir C. V. Raman, the organic Chemistry Department is under Professor P. C. Guha, while the Biochemistry Department, where two of the Council's Schemes are being worked out, is under Professor V. Subramaniam. Among other problems of agricultural interest included in the very wide and varied programme may be mentioned the studies of proteins of Indian foodstuffs (this does not overlap the work done at the Presidency College, Madras), of starches and enzymes, the oxidation of soil organic matter and the influence of iron and manganese oxides thereon ; while on the technical side, work is proceeding on the production of paints and adhesives from non-edible nuts, eradication of lantana, and chemical control of spike disease of sandal wood. Although I visited the whole institution I shall deal here only with the Council's schemes.

(1) *Preparation of manure from town refuse and waste material.*—This scheme started in January 1935 with a grant of Rs. 4,950 to be spread over two years. Mr. A. V. V. Iyengar was appointed to do the work, but after two months he left and was succeeded by Dr. J. G. Shrikhande, who in turn left after 8 months, and was followed at the end of December 1935 by Dr. A. N. Acharya.

The subject is important, and the location of the scheme is emiently suitable, as Professor Subramanyan is an authority on the nitrogen changes involved, and Dr. Gilbert Fowler, one of the leading experts on town wastes and sewage, resides at Bangalore and is interested in the work.

The method under investigation consists in composting town refuse with waste vegetation adding a nitrogenous "starter"—sulphate of ammonia, night soil, etc., allowing the heaps to undergo an initial aerobic fermentation so as to attain the maximum rise of temperature, then compressing them tightly in closed chambers. After three months the material was removed and analysed. The loss of dry matter was about 10 to 15 per cent., but of nitrogen was usually less.

In further experiments attempt will be made to simplify the procedure.

Considerable interest is being taken at a number of the agricultural experiment stations in this question of composting and a good deal of disconnected and unco-ordinated work is being done. I strongly recommend that the results obtained up to the present should be brought together by some competent impartial person and issued as a monograph which could serve as a basis for discussion and further experiment.

(2) *Quality of rice*.—A grant of Rs. 5,400 was made in December 1934 for a two year investigation on the quality of rice, the work being *done for the first six months* by Dr. V. N. Patwardhan and after that by Mr. A. Sreenivasan under the supervision of Professor Subramaniam. The subject was recognised as being too vast to be worked out in full and so was narrowed down to two problems :—

(*i*) an investigation into the conditions of storage of paddy and of the changes taking place during storage :

(*ii*) an investigation into the methods of par-boiling with a view to standardising the conditions so as to improve the quality of the marketable produce.

Consumers always prefer stored rice to fresh rice, claiming that it is either more palatable, or more digestible. Rice is generally stored as paddy, not after par-boiling, and the storage may be either in granaries in aerobic conditions, or in underground hermetically sealed pits where the conditions are more likely to be anaerobic. The experiments began on the hypothesis that the changes during storage would be a continuation of those taking place during maturation.

Par-boiling is now very widely practised : much of the rice grown in India, as well as that in the other rice-producing countries, is parboiled before it is milled. The process consists in steeping the rice in water for a period varying from 24 to 72 hours, then subjecting it to live steam till the husk slightly dehisecs and subsequently drying either mechanically or in the sun. Parboiled rice is considered to be superior in various ways to white rice : it is said (though without much evidence) to be more digestible, more sustaining, more palatable ; to remain for a longer time sweet after cooking, and to be less liable to breakage in the mill.

Previous work has suggested that material is absorbed from the husk by the grain during parboiling, so that there is less loss of nutritive value on subsequent milling : thus Aykroyd showed that highly polished parboiled rice is richer in Vitamin B and in phosphorus than raw rice milled to the same degree. The present work confirms and extends this result ; it holds true only for a limited degree of milling : beyond a certain stage there is no difference in composition between parboiled and white rice.

If the work is continued it should if possible become a joint investigation with Dr. Aykroyd of the Coonoor laboratories. Some tests with pigeons and with rats have already been made and they suggest that medical collaboration would be very useful.

Department of Agriculture, Mysore.—Bangalore laboratories.

Insecticidal value of plants used as fish poisons.

This work is not carried out at the Indian Institute of Science but at the laboratories of the Mysore Department at Bangalore. The grant is Rs. 15,288 to be spread over 2 years and the work began in January, 1935. It is under the direction of the Government entomologist, Mr. T. V. Subrahmaniam and the senior assistant chemist, Dr. B. T. Narayanan, the actual assistants being Mr. K. Lakshmi Narayana Bhatta, Chemist, and Mr. M. Puttarudriah, the Entomologist.

The work consists in making somewhat rough comparisons of the effects of a number of fish poison plants especially *Tephnosia candida* and *Mundelia suberosa* on a variety of insects. Considered as a preliminary investigation it serves a useful purpose for distinguishing useful from useless plants, and it could be extended to ascertain whether the plants lose their toxicity on cultivation : if not, there would be the possibility of growing some of them on the commercial scale. This type of work would be useful in view of the growing demand for vegetable insecticides.

The chemical work suffers from the circumstances that it is on too small a scale : to carry it beyond its present stage, where it is concerned mainly with the preparation of extracts, would require a large well equipped organic chemical laboratory with a staff of competent assistants. I do not recommend this, partly because of the expense, partly also because this fuller work is already being done at Rothamsted, in the United States, and elsewhere. If it were desired on general grounds that Indian workers should participate then the work should be done in one of the existing organic chemical laboratories such as Professor Ray's at Lahore or Col. Chopra's at the Calcutta School of Tropical Medicine. This is not to be taken as implying any reflection on Dr. Narayanan's competence to direct the work, which I certainly should not wish to call in question, but there are so many other urgent problems awaiting study that I cannot advise spending time on this.

The simplest and most effective plan is to concentrate on the biological tests, combining these with a definite but simple chemical examination which can be carried out in the existing laboratories. The survey of Indian insecticidal plants is too important a matter

to be dropped, and I suggest that the Chemical Assistant be sent to the Insecticides laboratory at Rothamsted for six months or more to work out, under Dr. Tattersfield, methods suitable for a survey of Indian insecticidal plants, and that while there he should learn the quantitative biological method of assessing insecticidal value, which is at present safer than the chemical methods.

Field experiments should be made with the cultivation of *Derris elliptica* and *D. malaccensis* to see if they are superior to the native plants and if so whether they can advantageously be grown for use in India.

Mysore, Sugar Cane investigations.

The climatic conditions prevailing in the Mysore plateau are well suited to the breeding of sugar cane, and work on this subject was started by Dr. V. K. Badami in 1912, though only on a small scale.

Since 1933 it has been aided by a grant from the Council of Rs. 21,000 spread over five years.

Dr. Badami sets out on the basis that all the noble canes are hybrids, hence he does not cross them with wild Saccharums like Saccharum spontaneum to introduce vigour. Instead he selfs them, when they produce seedlings of various kinds ; some being thin or reed canes and others thick ; some are rich in sugar and others poor. By selfing a few generations of selected seedlings, it is hoped to establish pure homozygous canes, rich in sugar, both thick and thin, and from this foundation stock he proposes to build up seedling varieties. This method was in fact extensively tested by Dr. Barber with the object of producing medium canes for North India, but it did not prove effective.

The work on cane breeding is not, however, confined to the crossing of promising parents : attempts are also made to induce artificial mutations.

It is known that X-rays will bring about changes in the chromosomes thus altering the characters of the resulting plants. When the late Director of Agriculture, Dr. Leslie C. Coleman, visited Java, he saw at the Klaten Experiment Station new strains of tobacco being produced by exposing the seeds to X-rays before sowing. On returning to Mysore he arranged to have similar experiments made with sugar cane bud sets and this has been done by Dr. Badami who has already obtained some interesting and promising results.

Single eye bud sets(1) of the local striped cane were treated with X-rays and then grown. About half of the resulting canes differed from the parent and formed a series of variations including pure yellow canes, pure red, striped canes, both yellow and red, some thin and reedy ; canes of varying degrees of vigour, some of which were much superior to the original local cane.

X-ray treatment of sugar cane seeds in Trinidad, Hawaii, Mauritius and Java, does not seem to have yielded valuable results,

(1) Work by Dr. A. E. Murneek on bud variations in the apple caused by X-ray is recorded by Stadler (Journal of Heredity, 1930, Vol. 21, pp. 3—19) but I know of no work on sugar cane buds comparable with Dr. Badami's.

but Dr. Badami attributes this to their using seeds from heterozygous canes. Dr. Badami is an ingenious investigator with a flair for this type of work. So long as he remains in charge some valuable results may be expected.

Other experiments at the Departments laboratories or at the Hebbal Farm.

The laboratories.—In addition to the usual investigations arising out of advisory work there are experiments by the chemist and the botanist on the Sandal spike disease which is of some importance to Mysore. The problem is obviously difficult and if it is desired to make much progress it should be put in charge of a good plant pathologist who would devote his whole time to it and find out more definitely the class to which the disease belongs and its relations to the associated plants.

The farm.—In addition to the usual experiments on crops—including tapioca—there are experiments on the crossing of sheep with a view to improving the wool : on the making of composts : and on beekeeping.

Mysore.—Fruit.

In view of the successful growth of apples at Bangalore it appears that their cultivation could be extended and there can be little question as to the advantage of doing this. Other fruits also do well. A scheme has been submitted to the Council by H. C. Javaraya, the Superintendent of the Government gardens in Mysore, but at present a senior marketing officer on the central staff of the Imperial Council of Agricultural Research, for research on Fruit growing and with some modifications it has been accepted, a grant of Rs. 46,200 being given to be spread over five years.

The Irwin Canal Irrigation Scheme.

While in Mysore I visited the experimental farm set up in 1931 as part of this irrigation scheme. It serves an area of about 100,000 to 200,000 acres of irrigated land of which 40,000 acres may be under a monsoon crop like paddy requiring a continuous supply of water, 40,000 under a dry crop requiring occasional water, and the remainder under any crop requiring intermittant irrigation throughout the year.

MADRAS PRESIDENCY.

The agriculture of Madras is characterised by the dominance of rice and millets among the food crops, these, however, being complementary to each other. One of the millets, Ragi, is almost confined to Madras and Mysore. Wheat is hardly grown at all but there are considerable areas under oil seeds and relatively large areas under fruit and vegetables. About one-third of the sown area is irrigated.

Madras University : Presidency College : Medical College.

(Visited December 13th and 14th, 1936.)

The Madras University was until recent years a co-ordinating body like the London University : it is now, however, establishing Research Laboratories, several of which deal with subjects underlying the Council's work. The Botanical Research laboratory is under the Directorship of Dr. M. O. Parthasarathi Ayyangar. Much of the work is concerned with the study of algæ, both of soil, of paddy fields, and of tanks. The diatoms of the river Cooum and elsewhere are also studied. The investigations are on pure botanical lines but it should not be difficult to effect some linking, or at least understanding, with the workers on the algæ of paddy fields at Dacca.

The University Biochemical Research Laboratory is directed by Dr. M. Damodaran : the work is largely concerned with the proteins, both animal and vegetable, but especially the latter. Studies are made of proteoclastic enzymes, and of the nitrogen metabolism of germinating seedlings.

The work of the Zoological Research laboratory, under Dr. R Gopala Ayyar, is concerned with marine biology, the lines being similar to those of the Marine Biological laboratory at Plymouth The life histories and life phenomena generally of the fishes found along the coast are studied. The knowledge thus accumulating will prove useful for any organised development of the sea fishing industry. As many of the animals described are but little known it would be useful to provide more help for identification and for giving greater detail in the plates and description.

The Director of the aquarium is interested in the culture of fresh water fish some of which—certain carps—grow so rapidly that, if introduced into village tanks at the beginning of the rains, they are large enough to be eaten before the tanks run dry.

Presidency College is one of the constituent Colleges of the University and several of its Departments deal with subjects important to agriculture. The Botanical Department is under Professor T. Ekambaran who took charge at the end of 1934 : the work includes morphological and physiological studies (absorption, transpiration, etc.). A scheme has been sanctioned for research on the developmental morphology and anatomy of the sugar cane-sorghum hybrids, and a grant of Rs. 8,600 spread over 3 years has been allocated. The work is to be done under the supervision of Professor T. Ekambaran in his laboratory but both Rao Bahadur T. S. Venkataraman and Dr. Janaki Ammal will keep in touch with it. The research should be recognised as being solely for the purpose of giving information, not of furnishing directly practical results though of course it has a bearing on the causes of "standing" power and resistance to lodging : it should be judged on its soundness, and not on any standard of practical value.

In the Chemical Department (Dr. B. B. Dey) peroxidases have been studied and also certain medical plants.

Special mention must be made of the work of the Department of Physics (Professor H. Parameswaran) although it lies outside the province of the Council.

Tobacco Substation of the Imperial Institute of Agricultural Research, Guntur, Madras Presidency.

In recent years there has been a change in the demand for tobacco : with the enormously increased consumption of cigarettes it has become necessary to concentrate more and more on cigarette tobacco and to give up the old varieties and methods used for cigar tobacco. The Council therefore established at Guntur, the centre of the well-known tobacco growing district, a substation of the Imperial Research Institute for studying the effect of environmental conditions on the quality of cigarette tobacco, giving a grant of Rs. 1,01,240 to be spread over five years.

Two well-known Virginian varieties, Adcock and Harrison's Special, are grown under a variety of conditions ; soils being brought from other parts of India for the purpose. Chemical investigations of the composition of cured tobacco leaf are proposed, but I am doubtful whether much useful information can be obtained by analysis of plants grown under the very artificial conditions necessitated when soils are imported from other areas. Flavour is a very complex and subtle phenomenon, rarely reducible to any chemical formula even in the simplest case, and tobacco presents a difficult problem. Chemical analysis can of course show how much nicotine is present and may thus eliminate bad samples, but a surer method would be to secure the co-operation of the buyers who have a fuller knowledge than anyone else of the consumers' requirements and who have their own standards to which the tobacco must conform if it is to find any place in the market.

Investigations on the virus diseases are also contemplated. If these are undertaken the work should be on a proper scale and done in a well equipped laboratory, in close touch with the English laboratories where virus diseases are studied, and if possible, with the Java laboratories also. Tobacco mosaic virus has a great tendency to throw off variants with different pathogenic properties. This makes the search for virus-resistant varieties somewhat hopeless since a variety resistant to one variant may not be resistant to another. A possible method of control, if every virus disease became common, is the introduction of comparatively innocuous strains of virus which may confer immunity against the more destructive types of disease.(1)

The Nilgiris.

Coonoor—Nutritional Research Laboratory.

(Visited December 19th, 1936.)

The work here is under Dr. W. R. Aykroyd but as it is not directly assisted by the Council, it falls outside the scope of this

(1) This method is studied in Java by Dr. T. H. Tung of the Dek Proef-Station : an account is given in Review of Applied Mycology, 1936, Vol. 15, p. 533 : 1937, Vol. 16, p. 414. Needless to say the method could be adopted only under the strictest expert supervision.

report. It bears so closely on the present enquiry however, that I have to refer to some of it some detail : this is done on page 19.

Potato Breeding at Nanjanad in the Nilgiris.

Parts of the Nilgiri districts are particularly well suited to potatoes, so much so that no fewer than three crops can be grown in one year, *viz.*,

(1) The main crop (rain-fed) planted in March-April, and lifted in August-September ; this is the most important and occupies about 6,000 to 7,000 acres.

(2) The second crop (also rain-fed) planted in August-September and lifted in December-January ; this occupies about 4,000 acres.

(3) The third crop (irrigated) planted in January and lifted in May : the area has increased from about 300 acres a few years ago to 1,200 acres at present.

A scheme for research on the breeding of potatoes is carried out at Nanjanad 9 miles from Ootacamund under the supervision of Mr. V. K. Subramanya Mudaliyar, a grant of Rs. 20,000 to be spread over five years being given for the purpose. The work consists in crossing Coonoor White, a variety found at Coonoor but of unknown origin, with various other potatoes, and observing the results. Work of this kind is to a large extent empirical, and some of the plants obtained have already been discarded. Coonoor white was chosen because it flowers and seeds profusely.

Difficulties were at first experienced in obtaining successful settings and in raising the seedlings, but they are believed to have been largely overcome. If this turns out to be the case further crosses should be definitely planned with the purpose of obtaining disease-resistant and heavy yielding varieties of commercial value.

It is often difficult to obtain seed for the second crop as that supplied for the first crop will not grow satisfactorily without a period of rest. Various chemical treatments are now known, however, for shortening the rest period of potato seed, and these should be tried.(1)

The Coimbatore (Madras) Schemes.

A group of Agricultural Institutions has grown up at Coimbatore, making it one of the most interesting and important research colonies in India. It stands at the foot of the southern extension of the Nilgiris on the east side, at the edge of the plateau some 1,000 to 1,500 feet above sea level which separates the coastal plain of the west from the wide expanse of the Coleron river system draining eastwards into the Bay of Bengal. The situation is very favourable to the growth of all tropical and subtropical crops, and the proximity to higher land widens the range of possible investigations besides improving the conditions of life for the workers.

(1) See, *e.g.*, F. E. Denny and L. Miller, Boyce Thompson Inst. Trans., 1935, Vol. 7, p. 157.

The annual rainfall is about 20 inches and comes from both monsoons. The south-west monsoon, however, which sets in about the beginning of June, brings only little rain and its effects are offset by high winds so that sowing can usually only be done in August The north-east monsoon which begins about the beginning of October brings more rain, and most of the annual rainfall is received then. January, February and March are usually dry, and thunderstorms often come in April and May facilitating tillage operations generally. Ample irrigation water is available, however, for all experimental work. The temperature is much less variable than in the north : it rarely rises above 100°F or falls below 60°F. In these circumstances plants can complete their growth and set seed without fear of damage by cold.

Both red and black soils are available for experiment, and all three types of cultivation common in the province can be carried out : associated respectively with the unirrigated red soils (cholam, gram, dry cotton, etc.) ; with the so-called "garden" soils irrigated from wells(1) (Cholam, Cambodia cotton, Ragi followed by Green Manure crop) ; and with the "wet" lands for which some copious supply of water is available for a short period from July onwards, and on which therefore paddy can be grown, or, if a more continuous supply is available from supplementary wells, much more profitable crops like betel vine, sugar cane, cocoanut palms, etc., become possible. Of all the stations I visited this is the best suited for breeding and growing a wide range of tropical plants. It is not surprising, therefore, that a number of Institutions should have developed here : the Madras Agricultural College, the Central Farm of the Madras Agricultural Department, the Imperial Agricultural Research Institute for producing sugar canes, special stations for paddy, sugar cane, cotton and millet.

The Imperial Agricultural Research Institute.

Sugar Cane Breeding Station.

The Station was started in 1912 and was the first of its kind in India. Prior to that date attempts at improvement had been confined to comparisons of certain canes imported from Java, Mauritius, or other parts of India, and multiplication of any that seemed promising. No breeding work was done because the seed would not set in the North, where the cane was important as a crop, while in the south, where it would set, the crop had little importance. In 1911, however, the All-India Board of Agriculture took the matter in hand with the result that breeding work was started here.

The Station was extremely fortunate in its first Director, the late Dr. C. A. Barber, who successfully overcame the very difficult problems involved in effecting cross fertilisation(2) and, by a happy

(1) About 3 to 4 acres can be watered by one well. The wells are about 25—40 ft. deep, and may cost anything from Rs. 500 to Rs. 3,000.

(2) Some idea of the difficulties is shown by the facts that the flower head of a sugar cane may have some 6,000 to 10,000 florets, ordinary emasculation being therefore impossible, and that the stem may be some 16 feet high, so that until the modern devices were introduced for inducing root formation from the nodes it was necessary to do the work while sitting on a ladder.

stroke of genius, recognised the advantage of indigenous varieties as parents, instead of relying on imported varieties : in particular he used the wild Saccharum plants, especially *Saccharum spontaneum*. He thus produced an entirely new set of varieties of great vigour and power of growth from which selections suited for various condition were made. These gradually spread over India, and the advantages of the work were so manifest that the Imperial Institute of Agricultural Research took it over in 1931.

Rao Bahadur Venkataraman followed Dr. Barber and further developed the technique ; he has shown considerable ingenuity in devising means whereby the troublesome procedure of cross fertilisation can be simplified and carried out more comfortably. Various devices are now worked out to alter the time of flowering so that two varieties which do not usually flower simultaneously can be made to do so, thus allowing crossing to be done. The times of planting may be so arranged that both varieties flower at the same time. Earlier flowering of one of them can be induced by shortening the hours of daylight, but the pollen is then much less viable. Flowering can be retarded by topping and allowing the side-shoots to develop and flower. Further, he has made crosses between Juar (*Andropogon Sorghum*) and sugar cane which if they should prove of practical importance as sugar producers, would have the further advantage that they grow rapidly and are ready for harvesting earlier than the usual sorts, thus prolonging the factory season. As they differ somewhat from ordinary sugar cane they are being studied in the Chemistry Department at Delhi.

Mr. Venkataraman has also developed methods for studying root development and is finding the relation between this and other characters of the plant.

He is further trying to obtain new varieties by mutation, mutants being induced by injury.

The problem of breeding sugar cane is complicated by the circumstance that three different kinds are needed : (1) medium canes which the peasants can crush in their mills for the making of gur, (2) thick canes which the factories can use, (3) soft canes for chewing : this last kind, however, is of minor importance. Both factories and peasants need a certain proportion of fibre in the cane as the residue after crushing is used for fuel ; the peasants in addition use the fibre for making ropes for their water lifts. The physical labour involved is extraordinary : some 200,000 seedlings are raised annually, and the work is possible only because Mr Venkataraman can divide it ; he takes special charge of the medium and thin canes, while Mr. Dutt takes charge of the thick canes. The general purpose in the breeding experiments is to produce a range of plants from which selection can be made for various properties : suitability to the conditions of different parts of India, resistance to various diseases or pests, earliness and high yield, lateness without degeneration[1] in the Indian summer.

Considerable success has already been attained, and the Coimbatore canes are known all over India.

(1) As shown by inversion of the sucrose and shooting of the buds.

Cytological studies of the Genetics of Sugar Cane.

GOVERNMENT OF INDIA SCHEME.

Cytological investigations are necessary for a complete understanding of the genetics of any plant and accordingly the Council has made a grant of Rs. 37,400, to last for 5 years, so as to enable them to be carried out. Miss E. K. Janaki Ammal spent a short time in England observing modern methods of investigation and has now begun the work at Coimbatore.

It is too early to attempt any summary of results or to express any opinion of the work. The investigation has the wider interest that it will show whether cytology can or cannot afford practical guidance to the plant breeder in India. If Rao Bahadur Venkataraman finds cytological help useful other plant breeders may do so also.

Developmental morphology and anatomy of the hybrids.

Professor T. Ekambaran is studying this at the Presidency College, Madras (page 199).

Chemistry of sugar cane. (*Cf.* morphology and anatomy.)

A parallel scheme dealing with the chemistry of sugar cane was submitted by the Madras Government but on the transfer of Mr. Viswa Nath to the Central Research Institute at Delhi the scheme went with him. The programme is very ambitious, including as part of one item—there are seven in all—the study of the formation of the carbohydrates in the leaf, one of the most difficult problems in biochemistry at which whole Departments have worked for years. Some of the other items are equally extensive. It would not be fair to the workers to expect much in the way of practical results in any limited period of time and on general grounds the work is more suited to a University where its value for the training of chemists and plant physiologists—which is very considerable—could be better utilised.

The grant, however, is not large : Rs. 23,000 to be spread over a period of three years, and the period should be completed. If at the end of that time any of the results appear likely to help in the selections or breeding of new canes a new programme could be submitted devoted expressly to that end.

A Research programme at an experiment station should always be definite ; otherwise the work becomes diffuse and the results too vague to be of much value.

There are, however, two important chemical problems which could with advantage be studied, but the programme should be quite clear. Certain canes bred from wild saccharums prove troublesome in the making both of sugar and of gur, presumably on account of some non-sugar constituent of the juice. An investigation into the cause of the trouble might suggest some way out of it : the work should be done jointly with an expert at a good sugar factory.

The second problem is largely physiological and would indeed need doing in conjunction with a physiologist : the study of the changes during the ripening period, particularly the effect of variety and of environmental conditions on the ratio of sucrose to the hexose sugars, which is of importance in the factory.

Madras Government Stations.

Anakapalle and Guddiyatam (Substations).

The work at these stations consists essentially in the study of varieties in relation to the different conditions : it is supervised by Mr. Kanti Raj and Mr. S. S. Patrudu Garu, the total cost over a period of years being Rs. 3,00,200 of which, however, the Council provide only one-half, *viz.*, Rs. 1,50,100.

I was not able to visit the stations, but responsible officers met me at Coimbatore and discussed their results with me.

The Anakapalle Station is old, having been established nearly 25 years ; its soil is a heavy clay loam : it is well situated in regard to the monsoon, receiving about 40 inches of rain a year, about 25 of which falls between June and October. The Guddiyatam Station is new : its soil is a loam, its rainfall is lighter and not so well distributed, June and July being dry, and the rain coming only in September to November.

In the Madras Presidency sugar cane is grown under two entirely different systems of irrigation : (1) Flow irrigation : where the water during the period of largest growth (July to December) is supplied by canal, though at other times (February to June : January to April) it is lifted from wells : (2) Lift irrigation : where the water through the period of growth (March to September or October) is lifted from wells, while in the later period (September or October to February) it is supplied by flow from tanks, and during the remainder of the year from wells. Under both systems the cane commonly grown is J. 247. The experiments under the "flow system" are made at Anakapalle since April 1933, and those under lift irrigation at Guddiyatam since April 1935. Irrigation being one of the chief items of expenditure in the cost of cultivation, experiments are made to ascertain how to make better use of the rain water so as to reduce the need for irrigation water.

A third condition may arise, however, whenever paddy and sugar cane are grown in adjacent fields, in which case the water from the paddy field trespasses and may cause damage to the cane through water logging the soil. Co. 243 has been found to withstand these conditions better than any other, and Co. 313 comes second. An enormous amount of data has been collected which, however, has not yet been summarised.

It is impossible to express a definite opinion on this work without seeing it, but so far as I can judge from a study of the results and discussing them with the Staff it seems to be well done and to promise good practical results.

It would be well to arrange that the actual workers (as distinct from the Directors) of these farms periodically meet, visiting the three farms in rotation—these two and Coimbatore.

Rice.

The Madras investigations on rice were begun by Mr. F. R. Parnell(1) in 1913. He worked out the methods of cross-breeding and of field experiment, and in two very important papers, which serve as models for later workers, he made a full analysis of the inheritance of colour characters in paddy. He further studied the probable errors of field experiments. He left India to take charge of the cotton research station at Barberton (South Africa) where he is engaged in producing new varieties of cotton.

The work was carried on by Mr. K. Ramiah, but, he, in turn, is also giving up rice for cotton, which he will study at the Institute of Plant Industry, Indore. Since 1915 the work has been centred at Coimbatore, but the Madras Government possesses four other rice stations, and as a result of the grant made by the Council a sub-station has been started in the north-east of the Presidency at Berhampur (Ganjam) now in Orissa. The grant sanctioned was Rs. 1,15,660 to be spread over 5 years.

The purpose of the work is to collect and study existing varieties of rice (measurements are taken on about 500 pure lines but the total collection now exceeds 1,300) and to produce in addition new ones: from all this material to select sorts better suited to the conditions of the various parts of the Presidency than the present ones.

The production of new sorts is accomplished not only by plant breeding in the ordinary way, but by seeking to cause mutation by devices such as X-ray treatment, which may alter the chromosomes and so change the plant.

Selection work is done at all the stations and has already resulted in the introduction of improved types which are being multiplied for distribution. Since some 70 per cent. of the rice grown in Madras is irrigated it is very important to find good early varieties. For the non-irrigated areas, it is equally important to find good drought resistant varieties, and everywhere disease resistance is needed.

In addition a number of cultivation and manurial experiments are made. It is shown at Berhampur that a broadcasted crop sown at the right time and well managed gives as good yield as a transplanted crop; that 40 to 60 lb. seed per acre is the optimum sowing rate; and that for transplanting, seedlings 30 to 40 days old are better than seedlings 50 or 60 days old. Green manuring is effective, and fertilizer nitrogen can be given in addition, sulphate of ammonia being a better source than nitrate of soda. Phosphatic fertilisers on the other hand had little or no effect. There was no evidence that the combination of nitrate of soda and sulphate of ammonia was better than sulphate of ammonia done as Dr. Dastur's laboratory experiments had seemed to indicate.(2) The experiments at Coimbatore show that the sulphate of ammonia is most effective at the time of

(1) Mr. Parnell was at first styled "Economic Botanist" and his work was restricted to cotton and paddy. In 1920 a cotton specialist was appointed and from then to the date of his retirement (1926) he confined himself to paddy under the title "Paddy Specialist".

(2) Other stations also agree excepting Trivandrum, on a poor laterite soil, where it was stated that the mixture gave better results.

forming the rudimentary ear, which, of course, varies with the location and the variety.

The Millet Section.

The work of this section is in the capable hands of Mr. G. N. Rangaswami Iyengar who was trained under Mr. Parnell. In the Madras Presidency the millets are the counterpart of rice, the area they occupy in the different districts being inversely proportional to the area under rice. The most popular millet in the Presidency is *Andropogon Sorghum*,(1) the juar of the north, but here called Cholam : the areas are :

	Million acres.
Andropogon Sorghum (Cholam)	4.8
Pennisetum typhoidem (cumbu)	2.9
Elusia coracana (ragi)	2.2
Setaria Italica (Tenai)	1.6

There are also other millets, including *Paspalum scrobiculatum* (Kodon) occupying smaller areas.

Cholam gives the best yields both of grain and fodder on either dry or irrigated land, though it is chiefly grown under dry conditions, the grain being esteemed more nutritious than that from irrigated crops. This may be true, but I could find no evidence : under irrigated conditions the protein content may be less than under dry conditions, other things being equal.

Ragi is preferred as an irrigated crop, and so is usually in the hands of men more economically sound than is the ordinary dry land farmer : improved strains are therefore more readily taken up.

Tenai has two advantages : it possesses a husk, and so is less liable to attack by birds and insects than the others, which are naked ; and its slenderness enables it to grow among cotton plants, thus fitting in with ryots' " Safety First " devise, the double crop.

Kodon is the poorest both in yield and in nutritive value, sometimes, indeed, the grain is actually cyanogenetic ; its only merit is that it will grow under extremely poor conditions and it is cultivated in places by the depressed classes.

The main purpose of the work is to find strains or varieties of these millets suited to the different local conditions, and where necessary, resistant to Striga, the flowering root parasite which does so much damage in many places. Immune and resistant varieties have been imported from Africa and will be used as parents in cross-breeding work. Attempts are further made to improve the juiciness of the Cholam stems so as to make them more palatable to cattle.

The work is being well done and should, in my opinion, be developed. In spite of its low economic value due attention should be given to Kodon in view of its special position as a poor man's crop : it should either be improved or replaced. The pulse *Dolichos lablab*, which is also included in the studies, should for the same reason receive adequate attention.

A remarkable phenomena has been observed on the black soils :

(1) For a full account of this crops, see J. D. Snowden, " The Cultivated Races of Sorghum ", London, 1936.

after a crop of cholam the yield of cotton is less, and the soil becomes much more compact, than after a crop of cumbu : the soil also contained more exchangeable sodium.(1) Much more field work will be needed to ascertain the facts but if they can be established beyond dispute—and not till then—an interesting laboratory investigation will become possible.

The Malting of Cholam.

Some 20 years ago it was shown by Rao Bahadur B. Viswanath(2) that malted Cholam could be worked up into foods resembling the various patent malted foods for infants and invalids. Some of the preparations were exhibited at the Madras Industrial Exhibition of 1917 and gained a gold medal ; nevertheless no industrialist took the matter up, and nothing more was done.

In June 1935 a scheme was started for studying the chemistry of the process of malting, the work being carried out under the direction of the Government Agricultural Chemist, Mr. P. V. Ramiah and by an assistant Mr. M. Suryanarayana. The amount of the grant is Rs. 11,660 to be spread over three years.

A certain amount of preliminary work has now been carried out but as yet little seems to have been added to what Rao Bahadur Viswanath had already described.

In my view the important problem here is whether it is worth while trying to set up a cholam malting industry : the chemistry of the process is of little interest unless that is done. I recommend therefore that the medical authorities should be asked to experiment with cholam malt as prepared by Mr. M. Suryanarayana, and to report whether it is superior to malted barley as a basis for infants and invalid food. If it is, then active steps should, in the public interest, be taken to establish the industry : if it is not, then the investigation should be discontinued and efforts should be directed to finding what kind of barley gives a satisfactory invalid food, and how, if at all, existing malting processes must be modified to furnish the new product.

Impressive figures were given me showing the value of imported malted foods, but it should be remembered that most of them are probably purchased on the recommendation of a doctor or a nurse, and it is doubtful whether a product that lacks this backing would succeed.

Fruit Schemes.

Parts of the Presidency of Madras are very suitable for the cultivation of fruit, apparently one of the most remunerative branches of agriculture. The areas in 1935 were as follows :

Mangoes	230,000 acres.
Bananas	140,000 acres.
Citrus and other fruit	15,000 acres.

(1) V. Ramanatha Ayyar, S. Kasinath and M. R. Balakrishnan, Current Science, 1935, Vol. 4, p. 99.

(2) Bulletin No. 1, Dept. Ind. and Agric., Madras, 1925.

Investigations on bananas are carried out at Coimbatore, and on mangoes and citrus at a special Fruit Research Station situated at Kodur (Cuddapah) in the plains.

The Council has made a grant of Rs. 66,000 to be spread over 5 years for the work at Kodur, and of Rs. 69,095 also over 5 years for the work at Coimbatore.

Coimbatore experiments on Bananas.—Bananas or Plantains have the advantage that they can be grown in wet conditions and consequently can be associated with the cultivation of swamp paddy. There are, however, many varieties, the fruits of which vary enormously in palatability, and it is essential that they should be sorted out and only the best of them grown : greater uniformity in produce should also be attained.

Mr. K. Cherian Jacob, who is in charge of this work, in a survey of the types of Indian bananas, found no fewer than 500 differently named varieties. When grown side by side a number were seen to be identical, but after elimination of duplicates there still remained some 50 or 60 distinct types. Selection from among these is proceeding. Still further improvement could be effected by hybridization, but this presents special difficulties, owing to the low proportion of fertile seed produced, which, however, Mr. Jacob thinks he has overcome and he proposes now to proceed with the work.

Close touch should be kept with the investigations of Professor Cheesman and Mr. L. N. H. Larter on the breeding of bananas in the West Indies.

The utilisation of undersized and unsaleable bananas is being studied ; they are being made into jams, jellies and floor ; and cut into slices or lumps which are dried in the sun and called crisps, nuts, figs, etc. The ryots on the west coast pound up the sun dried fruit into flour which they make into porridge for children ; only a particular variety is used, however ; this was found to contain 5 per cent. of protein, while other varieties contain 3 per cent. only.

Cotton.

Although cotton falls outside the scope of this report I must record the visit I made to see the experiments of Mr. V. Ramanatha Ayar. Cotton is not much cultivated in Madras, only 9 per cent. of the total Indian production being grown here. Nevertheless the Madras crop is far more important than this figure suggests, since most of it is the so-called medium staple cotton. There is the further special feature that cotton, which elsewhere is a warm weather crop, is in Madras a cold weather crop, being sown in September or October after the north-east monsoon and picked in the following March—May : a second flush comes from July to August and further pickings could be obtained but, as this late continuance of the crop leads to a high degree of infestation with the pink boll worm, the Pest Act requires that all Hirsutum cotton shall then be pulled out.

Cambodia cotton is the main American variety grown and is used as a parent in the breeding work because it is jassid resistant. An important part of the work is the search for earlier varieties, which would need less lifting of water.

Groundnuts (Arachis hypogaea).

Madras has a larger area under groundnuts than any other province, and therefore it is fitting that the research scheme should be placed here. The scheme is approved but not yet started : funds will, it is understood, be provided for five years.

The programme finally accepted by the Council includes as chief features the selection or breeding of varieties possessing high yield, high oil content, high shelling percentage and low free fatty acid content :(1) from these to select also drought resistant and disease resistant varieties. The effects of soil, climatic, manurial and general management conditions on yield and quality of oil will also be studied.

It is important that the work should be concentrated on these main items, and should not be allowed to become diffuse.

Sunnhemp : Samalkota Station.

Sunnhemp is important in several provinces and research schemes financed by the Council are in progress in Madras, the Central Provinces, Bombay and Bihar, while a scheme from the United Provinces has been considered. The co-ordinated schemes have the advantage that they permit of organised investigation under different conditions, and of detailed discussion of results.

Selection and breeding work with sunnhemp is complicated by the circumstance that the plant is normally cross-fertilized by large bees and will not readily set seed under a bag—the usual device of the plant breeder. Dr. Uppal at Poona has worked out a procedure which in his hands has proved successful (page 185) ; so also has the Assistant Economic Botanist in Bihar (1934). For the present, however, the work is confined to known good varieties except at Bihar where some selection is done : otherwise the programme is on similar lines at all four centres.

A scheme has recently been approved, with a grant of Rs. 1,500 spread over three years, for improving the quality of sunnhemp fibre. Known good varieties will be collected locally and from other parts of India and compared though there will be no selection or hybridising work. The effects of various factors such as seed rate, time of harvest, and various modification in the setting process on the yield and quality of the fibre, will be determined.

The programme appears to be sound and free from objectionable diffuseness : the workers should keep steadily to their main lines.

Other activities at Coimbatore.

I visited other organisations and Departments at Coimbatore but on which I make no report here as none of the Council's schemes are involved. Some of the results, however, bear on the Council's work.

(1) The Agricultural College. Principal—Mr. D. G. Munro.

(2) The Mycological Section.—Rao Bahadur S. Sundararaman.

---

(1) The free fatty acid content is greatly affected by the methods of storage and decorticating, and there may be no hereditary character involved.

Mosaic in sugar cane is controlled by rogueing infective material. Some highly resistant canes have been found.

Smut of cholam is successfully controlled by treatment of the seed with sulphur.

Methods of controlling Die-back in Citrus have been studied.(1)

(3) The Entomological Section.—M. C. Cherian.

A considerable number of pests have been studied since this Department started in 1912 under Mr. T. Bainbrigge Fletcher, R. N.

Mr. Cherian would like to take up the study of the relation of insects to the micro-climate within crops (page 183).

Also he wishes to develop beekeeping which appears to attract but little interest here.

(4) The Agricultural Chemistry Section.—P. Venkataramiah.

This was started by Dr. W. H. Harrison in 1906.

The natural deposits of phosphate rock occurring in Trichinopoly have been studied. Many fertilizer experiments have shown the advantage of nitrogenous and phosphatic fertilizer along with organic matter, especially leaf material.

Claims are made in regard to the influence of organic manures as distinct from the effects of the simple plant nutrients they contain, on the yield and quality of crops grown in soil. These, however, lack independent confirmation.

The work on mineral metabolism of dairy stock falls within the province of my colleague Dr. Wright.

A pasture survey of the Madras Presidency is being made under the aegis of the Council.

Studies in jaggery (gur) were begun by Mr. Viswanath and are continued partly here and partly by him at New Delhi.

Nitrogen fixation by micro-organisms is also studied.

(5) The Botanical Section.—K. Cherian Jacob.

A herbarium is maintained. Weeds are studied. For the work on bananas see page 209.

(6) Oil Seeds Section.—J. S. Patel.

The work was at first confined to ground nut (page 210), cocoanut (page 214) and castor, a sufficiently wide programme, but it has since been extended to other oil seeds.

(7) The Engineering Section.—Mr. Charley.

I saw here some ingenious improvements on the ordinary implements and water lifts.

Kodur.

Work was started at the end of 1934, the Superintendent being Mr. K. C. Naik.

The farm is classed as dry arable land and depends on wells for water supply. The rainfall is variable, about 25 or 30 inches per annum, roughly half of which is from the south-west and half from the north-east monsoon during 6 to 7 months in the year. The six

(1) See also Lyallpur.

months January to June are dry, except for slight showers in April and May.

Mangoes.—In spite of the popularity of mangoes it is difficult to obtain standard stocks capable of yielding fruit of known variety and quality. There is no uniform practice in the selection of stocks, and the local methods of propagation are unsatisfactory. It is proposed therefore to collect the numerous local varieties, to select the most promising, and to study the different methods of propagation and of cultivation : also to study the different species of Mangifera stock.

Similar work on mangoes is proceeding also at Sabour.

Dry farming research scheme. Hagari Station, Bellary district, Madras.

The Hagari scheme was started early in 1934, the total grant being Rs. 1,39,570 to be spread over five years. Mr. C. Vijayaraghava Acharya is the superintendent. I was not able to visit the station, but he and Dr. Subba Rao, the Soil Physicist, came to Coimbatore to show me the results.

The Station is an old one, having been started in 1906 for studying the possibility of irrigating the surrounding black cotton soil by pumping water from the Hagari river : the district is important since about one-fifth of the total area of Cholam in the Province is to be found here. The Station lies 80 miles south of the Raichur station, and the conditions seem to be generally similar, so that considerable similarity of results may be expected : it is about 140 miles to the south-east of Bijapur. The rainfall is about 17 inches, about half of which comes in September and October, and from then on till February there is but little more. The region contains both red and black soils. The red are lighter and more permeable : well irrigation is practicable and the problems are mainly economic. The black soils, however, are very heavy, often containing 50 per cent. or more of clay : they tend to be alkaline and impermeable, and well irrigation is often impracticable ; to make matters worse in heavy rainfall these soils are liable to considerable sheet erosion.

The two main soil problems of the Station are therefore, as at Sholapur and Raichur, the prevention of this erosion and the conservation of the September-October rainfall so as to serve as fully as possible the needs of the plants. The chief crops grown are cotton, sorghum and setaria. The crop work consists in making selections of varieties suited to the conditions, and considerable success is claimed for some of the strains now distributed. A pure line strain of cotton, Hagari 1 (*Gossypium herbaceum*) selected between 1920 and 1927, is said to be grown now on nearly 1¾ lakhs of acres and a further improvement on this is being sought. The improved sorghum has not, however, spread much ; but better strains are in sight. Better strains of setaria are also being sought.

Manurial experiments with compost, farmyard manure and artificial fertilizers are also made on modern lines. Some of them are based on previous experience that the manure is best applied direct to the cereal crop (here sorghum or setaria), allowing the

cotton to have the residual effect. No striking results were in any case obtained.

Owing to the uncertainty of the early south-west monsoon rains the ryots commonly grow mixed crops, usually a cereal and a pulse each in separate rows, in the hope that, if one fail, the other may yet succeed. Various mixtures are under investigation. This subject of mixed cropping should be more fully investigated.

Soil Experiments.—Bunding was found to reduce erosion and, when combined with ploughing, to conserve the water supply. As at Sholapur and Raichur, I consider that these experiments should not be confined to the Station, but that some of them, especially the bunding and ploughing, should be carried out also on ryots' land in order to serve as a lesson to the ryot if they succeed, or to the experimenter if they fail. Soil research is best achieved by comparing different results : and an experimenter who found an instance where the results differed from those he expected would have an opportunity for making advances that might have really important consequences.

The effects of different methods of cultivation and manuring on the moisture content of the soil are studied, and many physical observations are taken, the interpretation of which is at present obscure but may become clearer as the data accumulate. Similar measurements are being taken at the Sholapur and Raichur stations.

In justification for this vast amount of detailed measurement it has been urged that the agricultural experts must have precise information on the physical composition of the soil at the station and the movements of moisture therein before they are in a position to formulate schemes of dry farming practice for the benefit of the ryot. This is true only to a very limited extent : if one were compelled to wait for precise information on the movements of moisture in soil the present generation of ryots would probably get nothing out of the scheme. The subject is so complex that some use of the empirical method of trial and error is inevitable. A considerable amount is already known about dry farming, and it could be embodied in something like the Bombay scheme and tested at various centres. The physical measurements would fit in very well with this work : their proper purpose is to make comparisons between one soil and another, soils having similar "values" being expected, to that extent, to behave similarly in the field. For ordinary station purposes determinations of soil moisture under different conditions of treatment afford sufficient guidance.

At an early date it is desirable that all the actual research staffs of these dry farming stations should meet to compare their results, and that the mass of data should then be examined by the Council's statistician or in Professor Mahalanobis' laboratory to ascertain what records are worth continuing and what could be discarded.

Cocoanuts.

The Cocoanut palm is the chief money crop of south-west India and coir making is, next to agriculture, the chief industry. In Madras there are nearly 587,000 acres of cocoanut and a little more in Travancore where the area is exceeded only by paddy with 700,000 acres : an acre yields about 1,800 or 2,000 nuts worth even at the

present low price nearly Rs. 40. Indeed I was informed in Travancore that if a cultivator owned 50 cocoanut palms in full bearing he need do no more work.

The Madras Government maintains no fewer than four experiment stations devoted entirely to the study of cocoanuts, and the Council has sanctioned a grant of Rs. 48,000 to be spread over five years in aid of the work. New varieties are obtainable by cross, self, and natural pollination.

Cocoanut trees grow for at least 50 to 80 years, and consequently great care is needed in making the original selection. Trees take about 10 years to come into full bearing and it is undesirable to have to wait so long before choosing them ; it is very important therefore to find criteria whereby the future performance of a seedling can be forecasted. This forms part of the Madras scheme : preliminary trails suggest that the time required for germination, the rate of production of leaves and girth, and the height of the stem, may afford suitable indications. The yield and quality of copra and of oil, and the factors determining quality of coir and of oil, are also studied. Other suitable subjects for experiments would be the effects of clean cultivation, which is said to double the yield, also of manuring. Sulphate of ammonia and ashes are stated to be effective : this suggests that potassic fertilizers might prove useful as indeed they frequently are on fruit trees.

In view of the serious competition from Ceylon and Malaya there is no question as to the urgency of the work, and it can suitably be done at Madras.

TRAVANCORE.

Travancore : Diseases of the cocoanut.

Two diseases are doing a certain amount of damage : a leaf rot and the wilt or root disease. The leaf disease seems to have been first observed in Cochin about 40 years ago, and has spread widely into Travancore, while the root disease was first observed in Central Travancore about 30 years ago and is now spreading. In neither case is any effective treatment known. Two plantations, each of 4½ acres, at Kayamkulam, where both diseases occur, have been purchased by the Government of Travancore and a plant pathologist is to be appointed under the Council's scheme now sanctioned, and for which a grant of Rs. 25,500 to be spread over 3 years has been allocated. The first search will be for the causes of the diseases : whether fungal, bacterial, virus or physiological. A small field laboratory has been erected on the plantation but better facilities will be available at Quilon, a pleasant town not far away, to which there is a good road, so that the carrying out of the work should present no difficulties. The Travancore mycologist, Mr. K. Varghese, is familiar with the general nature and effects of the disease.

Should the diseases be found to do serious damage in Madras it would be desirable to take up the investigation at Coimbatore also, as the conditions in the two States differ and results obtained in one, while suggestive and helpful to the research workers, might not necessarily hold in the other.

Travancore: the backwater in course of drainage and reclamation.

SUMMARY OF REPORT AND RECOMMENDATIONS.

The Imperial Council of Agricultural Research has admirably discharged its primary duty of co-ordinating and promoting agricultural research in India, at any rate in regard to crop production, with which alone this Report is concerned. The Council has been able to arrange that all the factors affecting the production of each of the more important crops should be studied by one group of workers: the results can now be brought together and put into a form in which they can be used by the agricultural officers. A vast amount of pioneering work extending over a wide range has been accomplished.

A stage is now reached where a reorientation of the Council's activities should be considered.

It may be laid down as a broad principle that the investigations fostered by the Council should be for the express purpose of improving agriculture. The great need now is for fuller use of existing knowledge, rather than the accumulation of more knowledge, for work on the cultivator's fields rather than in the laboratory.

The Council's programme should, in my view, be lightened by handing over to the Universities all investigations of a scientific or non-technical nature and setting aside a certain fraction of the grant for this purpose. The grants made by the Council to Universities should be primarily for the purpose of fostering research in subjects allied or basic to agricultural science and practice and for training graduates in research methods, but the investigations should not be required to have an agricultural bearing. So far as research is concerned, it is the teacher and not the subject that counts, and the Council should be empowered to make grants to University Departments where good work is being done so as to provide one or more additional assistants who could subsequently, if needed, be attracted into the agricultural service.

Much of the research in agricultural science done in India is not as widely known as it deserves to be and I recommend the preparation of a series of monographs by competent persons setting forth the results obtained by Indian workers and pointing out how they differ from those obtained elsewhere.

Agriculture in India is not merely an industry but the mode of life of a large part of the population. The scope of the Council's work must therefore be much wider than if the subject were purely a branch of technology.

It is not sufficient for the results of the research work simply to be published in the Council Journal: the Council should have powers to undertake the much more difficult task of arranging for

them to be put into practice. The Council should also act as a Development Commission, stimulating extension work by the Departments and commercial exploitation of useful discoveries. This would involve additional staff to take over various duties so as to leave the senior staff free to plan ahead and to think out the problems involved. This extension of the Council's activities would involve additional expenditure necessitating an increase in its grants.

On the other hand Provincial Departments should contribute substantially to investigations made at their Stations on subjects of importance to them.

By far the largest part of the land of India is used for producing food crops intended for home consumption. Investigations on these crops should be made in conjunction with the human nutrition experts who should advise how far existing dietaries are deficient and what supplementary crops, vegetables, fruits, etc., should be grown in order to make up the deficiencies in the various regions. The Council's investigations should be directed to increasing the output per acre of food crops with a view both of ensuring full supplies and of liberating land for the growth of the supplementary crops and of fodder crops for the production of milk.

This increased productiveness is the main problem to which all others should be subordinated.

Investigations on quality of food crops should be made only at the request and under the close supervision of the nutrition experts except where specific marketing problems arise.

Certain problems relating to various crops should receive early attention.

Wheat.—In view of the fact that the export trade has fallen considerably and the home consumption increased a decision should be reached as to the future policy. If the recapture of the export trade is proposed then vigorous steps must be taken to increase largely the area under those varieties acceptable to the modern English market. If, on the other hand, the home market is to be the chief consideration, then the varieties should be tested for their suitability to the local mills and the making of chapatis, actual cooking tests being used.

Barley.—Recent developments in the United States suggest that Californian 6-rowed barley may not be available on the English market in such large quantities as hitherto, and this may create a good opening for Indian barleys. The varieties placed high on the list by the Institute of Brewing should be grown on a sufficiently large scale to ensure adequate supplies for the development of a permanent export trade. The export of cheap barley, however, should not be encouraged owing to its high content of protein which has considerable value in India.

Vegetables.—Every effort should be made to extend the cultivation of potatoes and other vegetables, particularly of the more hardy kinds, the list to be drawn up in conjunction with the nutrition experts.

Fruit.—The hill regions offer considerable scope for the ordinary English and Mediterranean fruits, and the plains and the Peninsular for tropical and subtropical fruits—mangoes, citrus, bananas and others. The cultivation of fruit should be extended where possible and a distinction should be made both in experimental work and in action between production for the village and production for the market. Much confusion in regard to varieties needs straightening out: methods of propagation have to be developed, and above all, supplies of young trees true to type must be worked up for distribution.

Along with fruit growing for the market go various subsidiary industries, especially fruit preservation and the making of containers, besides minor activities such as beekeeping and poultry keeping, both of which go well with fruit growing.

Transport is, however, a usual limiting factor and this should be improved wherever possible.

Grass and Fodder Crops. (1) *Grass.*—The Reports on nutrition lay great stress on the need for augmenting the milk supply and this resolves itself finally into an increase in the amount of grass and fodder crops available. Some 10 per cent. of the livestock population have to forest grazings. Various difficult problems of administration, soil erosion, and deterioration of herbage are involved, and I recommend that the Council call for a report by a forester, an animal husbandry expert, and a soil expert, making recommendations for improving and developing these grazings and that the Council should urge upon the proper authorities the need for taking active steps to carry out these recommendations.

The other grazings, which provide for some 90 per cent. of the stock, should form the subject of a second Report on which action should be taken. They include a very wide range varying from fairly good grassland down to virtual waste land. Improvement may be possible by reseeding, selecting for this purpose varieties and strains of indigenous grasses, and introducing drought resistant varieties from Africa such as the Woolly Finger grasses, *Digitaria seriata* and *D. Pentzii.* More experiments on management are also needed : on rotational grazing, the effect of period of the year, and of manuring: these all require that the land should be enclosed. Experimental work on this subject should as far as possible be done on actual grazing land.

(2) *Fodder Crops.*—Where water is available fodder crops can be grown and they not only provide food for the animals but indirectly increase soil fertility. Berseem is particularly useful and steps should be taken to increase the seed supply: the North-West Frontier

Province appears to be a suitable source. Napier grass has done well and other fodder crops deserve investigation. The possibility of silage making should be further examined. The more intimate fusion of agriculture and livestock husbandry is one of the most hopeful ways of improving Indian agriculture.

The improvement of farm implements, and particularly of the bullock cart would reduce the need for the present large animal population and so enable the remaining animals to be better fed.

Cash Crops.

The investigations on cash crops should be done in close association with expert users and buyers of the crops. Good examples of close co-ordination are afforded by the Tea Research Institute. Tocklai, and the Cotton Research Laboratory, Matunga. Malting barley is also adequately dealt with. On the other hand, the arrangements for wheat and rice are less satisfactory: in neither case is the purpose of the work sufficiently definite. It is necessary to decide on the market for which the experimenters are to cater, and then to associate competent market representatives with the enquiry.

The investigations on sugar cane are on sound lines: most of this crop is used for making gur in the villages, and the experiments on the improvement of the mills and evaporating plant (including the furnace) should be pushed forward with the aid of competent engineers. Experiments on factory technique are carried out at the Harcourt-Butler Technological Institute, Cawnpore.

Broadly speaking it seems undesirable for the Council to undertake Technological investigations and the new Sugar Committee could quite properly carry on this work.

Some way should be found out of the present difficulty of putting into factory practice the results obtained in the various technological investigations at the Sugar Research Institute, at Dehra Dun on forest products, and elsewhere. The difficulty in India is not so much to discover or to invent, as to exploit.

Other Crops.

The possibility of extending cultivation of cinchona and insecticidal plants should be discussed with the scientific officers of the tea and coffee plantations, especially as the former are limiting their areas under tea as a result of trade agreements.

Methods of increasing the output from the land.

(1) *Improved varieties.*—The finding of new varieties by selection and breeding is in general very well done: it is indeed some of the best agricultural work in India. It is necessarily localised, because the varieties best suited to one place may not be best suited

to another: and it is continuing work because no selection can ever be final. It has now in the main passed beyond the research stage and become essentially a combination of routine operations, more suited to the Provincial Departments than to the Council. Nevertheless the Council will always have an important part to play. It is the only body with full knowledge of all the material available for work on breeding or selection of crops; and it is in a position to arrange for exchange of material and to decide what work in a provincial Department should continue to be carried on if some financial stringency threatened to endanger a useful investigation.

More work is needed on the millets, the pulses, and the oil seeds.

The work would be put on to a less mechanical and more definitely scientific basis if it could be associated with a first class geneticist, good enough to command the respect of the men now engaged in the work, and to be accepted by them as a leader. Unfortunately no man of this type is at present in sight.

Improved varieties have not been widely taken up, except of sugar cane and jute: partly because of the difficulty of obtaining seed. I recommend that the Council enquire into the methods of distribution adopted in the various Provinces and States, and consider the desirability of finding means for speeding it up.

(2) *Better control of pests and diseases.*—In general each of the more important groups of crops should have its own staff of entomologists and plant pathologists: cotton, sugar cane, the food crops, each presents special features and no one man is likely to succeed with all. Surveys should be made to ascertain which pests are increasing and which are decreasing and to collect material for ascertaining the effect of conditions on the intensity of attack. When these are known it becomes possible to see how far changes in conditions or methods will obviate the attack. Direct control by chemical means is sometimes the only possible method, and the work on vegetable insecticides should be continued, with some modification of programme. Biological control presents various difficulties, but should be studied.

In view of the importance of insect pests in India, and the need for finding means of control, I recommend that a visiting expert of high standing be called in to advise as to the most suitable types of measures to be taken.

The search for resistant varieties must always continue: it is more useful for fungus diseases than for insect pests and in any case it is not final: so-called "resistance" often means only that another variety growing close by is preferred; and even actual resistance may break down.

It is very important, however, that some central authority should have power to deal administratively with plant diseases and pests for the whole of India. With increased speed of transport it is almost impossible to keep out disease organisms from other countries

but it is far easier to deal with an invader at an early stage than to wait until it has spread into every Province.

The Council, however, should not be concerned with the executive control of diseases and pests: its duties should be to arrange for research and advice into the most suitable means of dealing with them.

(3) *Improvement of the water supply for crops.*—This is one of the most important of all agricultural problems in India and perhaps the most difficult. It is too big to form part of a programme, and I recommend the establishment of a Central Irrigation Station for all-India where the agricultural problems can be worked out. At this station the relations of soils, water, and growing crops would be studied, also the interaction between salt water and soil, the reclamation of salted and alkaline land, the movements of subsoil water, and the agricultural effects of various sequences of crops.

Provision should also be made for more complete co-ordination of the investigations on dry farming, and for linking it up with the work of the proposed Irrigation Research Station.

(4) *The Conservation of Soil fertility.*—(*a*) *The prevention of erosion.*—While further research on soil erosion should continue, the chief need now is for action rather than for more research. Protection against erosion should be a State responsibility and each erosion area should be dealt with as a whole. An Erosion Conference should be held annually at which forestry, animal husbandry and soil experts meet the agricultural officers and advise as to what measures should be taken: the appropriate Minister should then have power to carry out these measures and to distribute the cost over the lands protected.

(*b*) *Manuring.*—More systematic schemes of manurial trials are necesary in order to test the relative values of nitrogen in artificial ferilizers, farmyard manure and composts, and the values of phosphate and potash. Simplified schemes should be carried out on cultivators' ground so as to discover what new factors, if any, come into play there and to find also how far the stations results hold generally.

Green manuring should be more systematically studied.

A Report on the manurial trials fostered by the Council should be drawn up by the Statistician, with recommendations for a more systematic treatment. If they can be obtained, the results of the extensive trials carried out recently by the large fertilizer organisations (Imperial Chemical Industries: the Potash Syndicate:) should be included in the survey.

Next to an improved water supply an increased supply of farmyard manure would probably do more than anything else to augment the output from the land. Additional supplies of fodder crops would

Children taking their eggs to be marketed.
Dr. Hatch's Co-operative enterprise, Martandam.

add to the amount of farmyard manure but the surest way of doing this is to reduce the necessity for burning it by providing alternative sources of fuel. The Forestry Department should be consulted as to suitable ways of planting tree belts that could provide shelter, fodder and fuel, and protection against erosion and dust storms.

The special difficulties of Indian agriculture.

One of the most serious defects of Indian village life is the absence of an educated middle class actually engaged in farming. Students from agricultural colleges, who might be expected to form this class, do not take to farming, but strong efforts should be made to induce them to do so. The experiment of establishing Colony villages in the canal areas of the United Provinces seems to offer one method of solving the problem. Generally speaking specialised farming such as cotton growing, fruit farming, seed production, etc., afford better prospects for a trained man than ordinary farming.

The co-operative movement can hardly be expected to achieve as good results as in Denmark owing to the wide difference in conditions. The experience of Bombay and the Punjab is, however, that something can be achived if there is firm guidance from outside, and probably suitable modifications in this direction can be devised.

The consolidation of scattered and fragmented holdings is so important that officers found to be successful in arranging it should be encouraged to remain at the work and should not be under the necessity of seeking advancement in other directions.

Owing to the importance of fruit and vegetable growing in the villages, and the desirability of planting more trees, school teachers should be encouraged to take up gardening and to undertake some of this planting with the children. Where possible, a school garden should be established.

The insufficiency of subsidiary industries is a well recognised weakness of Indian village life: the cultivator has long slack periods during which, if he had the opportunity, he might be increasing his income. An expansion of the cropping scheme could be arranged to utilise some of this time. Poultry keeping offers some possibility of success over a wide area as shown by the results of Mr. A. E. Slater in the United Provinces and of Dr. Hatch at Martandam in Travancore; beekeeping is possible in the hill regions. The ideal occupation would be cottage industries but apart from weaving and a few localised industries, these are hampered by the very difficult problems of marketing.

Bridging the gap between the Experiment Station and the cultivator.

By far the most important and most difficult task before the agricultural officers in India is to bridge the great gulf separating the agricultural experiment stations and the few large scale farmers

from the peasants who cultivate by far the largest proportion of the land. It is not new science so much as fuller use of existing science that is needed, and the Council should order an enquiry to discover how best this could be done, and to urge upon the proper authorities the need for taking all steps possible to this end. The extension officer should be recognised as a very important member of the staff and really competent men should be encouraged to continue at the work and be under no necessity to seek promotion out of it. The possibilities of broadcasting should be fully tested and means should be devised for the rapid answering of enquiries that have come in as a result of the talks. It should be impressed upon the staffs at the experiment Stations that they have a responsibility to the cultivator: that they must not shelter themselves within the walls of the laboratory in the hope that somehow their work may find practical application: they must make the field and the crop their centres, and as early as possible set out experiments on cultivators' land so as to widen the scope of their enquiry.

Demonstrations should be made by means of holdings taken as a whole *in addition to those on individual plots, and the staffs of the* experiment stations should be expected to carry out simplified forms of their experiments on cultivators' land, unless there was good reason to the contrary.

The Imperial Agricultural Research Institute, Delhi.

The Institute both because of its tradition and in virtue of its equipment should take a leading part in agricultural research in India. It can best accomplish this by working in close collaboration with the Imperial Council of Agricultural Research which, as the actual agent for the co-ordination of agricultural research in India, should be in a position to require the inclusion of specified items in its programme of work. Among other important subjects which could be handed over to the Institute are the devising of statistically sound methods of sampling soils and crops for approximate and accurate investigations respectively; the collection and collation of the results of the numerous local soil surveys that have been made: surveys of insect and fungus pests and of physiological and other diseases. In carrying out its own programme the Institute should carefully avoid the common faults of keeping the work too much in the laboratory: it should centre its investigations on the field and it should study a few problems thoroughly rather than a larger number superficially.

The Staff.

Suggestions are made in regard to training and qualifications of staff, and the difficulty of finding good leaders is emphasised. Good officers who excel in either research, extension work, or in persuading cultivators to consolidate their holdings, should be kept at their work and should not be compelled to seek promotion outside of the sphere in which they have proved their capacity for success. Although the Council's schemes are by their nature temporary the research staff should after a probationary period be given certain

advantages of permanence: in particular a provident fund scheme should be set up for them, a Register of competent workers should be maintained so as to help the men to find other posts, and a permanent cadre of selected workers of proved merit should be formed for the purposes of carrying out investigations wherever this might be necessary.

The improvement of the village.

The efforts to improve agriculture are likely to be unavailing unless the villages are improved and made fit for good cultivators to live in. This work has a deep personal side and could never be accomplished without enthusiasm and the missionary spirit; but it needs a solid foundation of accurately determined knowledge, and careful impartial consideration of the probable effects of proposed measures. The Council could probably better than any other body arrange for this to be done by organising surveys or other enquiries.

It should also arrange for a Report on methods of effecting consolidation of holding and of cropping, and consider what steps could be taken to hasten these changes.

General Recommendations.

(The detailed recommendations relating to the research schemes are given under each section.)

(1) The success of the Council's efforts shows that its general organisation and research programme are both sound and that it is a very effective agent for the improvement of Indian agriculture. My proposals are for an extension of its activities but always with the same purpose: increased production from the soil of India.

(2) An organised research scheme implies a definite plan for agricultural improvement and means of ensuring that the results of the research work are put into practice. I recommend therefore that *the powers of the Council be widened to comprise developmental activities*, as well as research activities.

(3) The work on crops sold in the open market (cash crops) should be done in association with the expert buyers or users of the crop. As a crop becomes of sufficient importance it should have its own Committee and specialist staff, as now happens for cotton and jute and will soon be the case for sugar.

(4) The work on crops mainly retained for food (food crops) should be done in association with the nutrition experts, who should advise as to the most suitable means of making up deficiencies in diet. The Council on its Developmental side should arrange for the recommendations to be put into practicable form. A Survey showing broadly the quantities of food produced in the various Provinces should be made *so as to provide a basis for joint action* by agriculturists and nutrition experts in improving the schemes of food production in the villages. The newly appointed liaison officer between the agricultural and the Health (nutritional) Departments could be of material assistance in this work.

Fodder and grazing committees should be set up for each Province so as to examine the possibility of increasing the food supply for animals.

(5) Part of the Council's funds should be used for promoting scientific research at the Universities on subjects basic to the science and practice of agriculture. This financial aid, however, should be essentially personal: it should be given only to enable an investigator of proved capacity to develop further his own main line of research. No question of possible practical value should be raised: in training for research it is the man and not the subject that matters.

(6) On its developmental side the Council should have resources:—

(1) to put into practical from the dietetic recommendations of the nutrition experts;

(2) to stimulate activities directed to the bridging of the gap between the experiment station and the cultivator;

(3) to plan extensions of dairy husbandry, fruit and vegetable growing, poultry keeping and other specialised branches of agricultural production in relation to transport and marketing facilities and to co-operate with the Departments in putting them into practice;

(4) to arrange for the setting up of organisations for the multiplication and distribution of approved stocks of seed, sets, and fruit trees:

(5) to advise the Government in regard to other action that could usefully be taken for the improvement of agriculture or the avoidance of some impending loss of soil, crop or market.

(6) to arrange for the exploitation of results of commercial interest obtained at the research stations, *e.g.*, the conserving of fruit and vegetables.

(7) The Council should set up a Soil Conservation Committee whose functions would be:—

(1) to arrange for the collection and collation of results of manurial trials and for the putting into practice of suitable results: the co-operation of the experimental staff of the large fertilizer organisations being if possible secured for this purpose;

(2) to watch closely regions liable to erosion, calling periodical conferences of the Departments concerned, with a view to working out schemes based on the physical rather than the political boundaries;

(3) to arrange for the collection of results of soil analyses, and the accumulation of material for a soil map of India;

(4) to help Departments where necessary in making surveys in irrigated regions or wherever salt or alkali may

cause trouble so as to ascertain whether or not it is spreading : to arrange also for reclamation of deteriorated soils;

(5) to examine the cultivable waste lands and report how far they can be better utilized.

(8) The Council should call for a report by an agrostologist, a forester, an animal husbandry expert and a soil expert, under the chairmanship of the Agricultural Expert to the Council, on the grazings available in each Province and on the methods of improving them: it should then encourage appropriate action.

(9) The Council should set up a Crop production Committee whose function should be:—

(1) the consideration of the cropping schemes, much on the lines adopted by the Crop Planning Conference, with a view to advising about desirable extensions or curtailments of areas under particular crops, improved sequences or rotations, fodder crops, etc.;

(2) the general oversight of the programme of research work on crops and examination of the results: the framing of schemes for putting accepted results into practice;

(3) the organisation of watching services to reports on the incidence of insect and fungus pests, noxious weeds or other threats to crop production and to arrange for the working out of control measures with the help of some visiting expert if necessary. The Council would then advise the Government as to any steps that should be taken.

(10) In view of the supreme importance of water supply to the growing crops I recommend the establishment of a separate research Institute for the study of irrigation and water relationships to soils and crops: also of more unified direction of the work on dry farming.

(11) None of these proposals can attain much success unless the standard of country life is raised and this necessitates the settlement of more educated men and women on the land. An enquiry should be made as to the working of the various colonisation and settlements experiments in the Punjab, the United Provinces, and elsewhere and steps taken to institute large scale trials of promising methods. The influence of a colony of good cultivators on the surrounding district would be out of all proportion to their number.

(12) The machinery at the disposal of the Council for carrying out this work should consist of—

(a) the Imperial Agricultural Research Institute, Delhi, which should work in close co-operation with the Council, and whose programme would largely be determined by the problems confronting the Council;

(b) A Marketing branch:

(*c*) a cadre of proved investigators, selected gradually from among the temporary staff now engaged on the Council's schemes: these men would be sent to various stations to deal with difficult problems for which the local resources were inadequate;

(*d*) a staff of temporary investigators as at present. I recommend, however, that their Status be improved by setting up a Provident Fund and by establishing a Register of approved persons which should be available to Departments, organisations or private employers wanting scientific workers.

(13) These recommendations if carried into effect will necessitate an increase in the grant made to the Council. I see, however, no alternative to the acceptance of this situation. The Council is the co-ordinating agency which provides invaluable assistance to the Provincial Agricultural Departments and will afford still greater help if it is given the wider developmental powers that will enable it to bring to fruition investigations which at present stop at the experimental stage. These Departments between them spend over 200 lakhs of rupees annually, a large sum and yet it amounts to little more than 1 anna per acre sown. The Council's regular grant of 5 lakhs is augmented for various purposes but its income is in my view inadequate for its important duties and the need for additions to its resources should be recognised, at any rate for the next few years, if progress is to be made as rapid as desired.

APPENDIX.

List of schemes visited and reported upon.

Nos.	Places of visit.	Names of Schemes.	Sanctioned cost.	Name of the person who is doing the work.	Person or Institution in whose name the grant is made.
			Rs.		
1	Bombay ..	Visit to the Technological Laboratory of the I. C. C. C.	..	....	....
2	Delhi ..	(1) Research on the Chemistry of sugar cane, I. A. R. I.	23,000	R. B. B. Vishwanath ..	*Government of India.*
		(2) Sugar cane Insect Pests Scheme, I. A. R. I.	96,000	Mr. P. V. Isaac	Do.
		(3) Investigations on Mosaic and other sugar cane diseases, I. A. R. I.	1,04,980	Dr. B. L. Chona	Do.
		(4) Statistical section at the Head-quarters of the I. C. A. R.	86,380	R. B. M. Vaidyanathan ..	Council's Scheme.
		(5) Economic enquiry into the cost *of production of* crops in the principal sugar cane and cotton growing tracts in India.	5,25,800 The cost is met in equal shares by the I. C. C. C. and the I. C. A. R.	Mr. R. D. Kapur. Chief Economist and provincial workers.	Do.

Nos.	Places of visit.	Names of Schemes.	Sanctioned cost.	Name of the person who is doing the work.	Person or Institution in whose name the grant is made.
			Rs.		
3	Karnal ..	(1) *Botanical Substation* I. A. R. I. ..	2,63,930	Mr. *Kashi Ram and* Mr. R. B. Ekbote.	Government of India.
		(2) Sugar cane Substation I. A. R. I. ..	1,32,000	R. B. Venkataraman and Mr. G. V. James.	Do.
4	Agra	Investigations on cereal rusts by Dr. K. C. Mehta.	1,34,760	Dr. K. C. Mehta	U. P. Government.
5	Muzaffarnagar ..	Sugar cane Research Scheme ..	1,01,260	Mr. R. L. Sethi and Mr. Imdad Ali Khan.	Do.
6	Nagina ..	*Rice* Research Scheme	1,39,660	Mr. R. L. Sethi and Mr. T. R. Mehta.	Do.
7	Shahjahanpur ..	(1) Sugar cane Research Scheme ..	1,01,260	Mr. R. L. Sethi and Dr. R. N. Mathur. (Physiologist).	Do.
		(2) *Scheme for seedling trials* ..	11,230		
8	North-West Frontier Province, Peshawar.	Sugar cane and Fruit Research ..	..	....	....
9	Quetta ..	Fruit Research	..	....	....
10	Sakrand ..	Crop Research for Sind	..	....	....
11	Karachi ..	Special Locust Research Staff ..	5,13,353	R. B. Y. Ramchandra Rao, Mr. R. N. Batra (Ambagh), Dr. M. L. Roonwal and Mr. S. M. Taqui Ahsan (*Pasni*).	Council's Scheme.

12	Poona ..	(1) Agricultural Meteorology Scheme	1,07,950	Dr. L. A. Ramdas and R. J. Kalam Kar.	Government of India.
		(2) Cold Storage Research Scheme, Bombay.	90,154	Dr. G. D. Cheema	....
13	Padegaon ..	Sugar cane Research Scheme, Bombay	3,86,402	Rao Sahib B. P. Vagholkar and Drs. R. D. Rege and J. K. Basu.	Government of India.
14	Sholapur ..	Dry Farming Research Scheme, Bombay.	2,35,000	Mr. N. V. Kanitkar and Dr. J. A. Daji replaced by Mr. V. N. Gokhale.	Do.
15	Raichur ..	Dry Farming Research Scheme, Hyderabad.	59,380	Dr. P. G. Krishna	Hyderabad Government.
16	Madras ..	Visits to University and Research Laboratories.			
		(1) Sunn hemp scheme ..	1,500	Recently started	Madras Government.
		(2) Groundnut scheme	57,100		
17	Bangalore ..	(1) Research scheme on the quality of rice.	5,400	Mr. A. Sreeniwasan under Professor V. Subramanian.	Indian Institute of Science.
		(2) *Preparation of Cheap Synthetic* Manure from town refuse and waste material.	4,950	Dr. C. N. Acharya under Professor V. Subramanian.	
		(3) Insecticidal value of plant fish poisons and other forest products.	15,288	Messrs. Lakhshmi Narayana Bhatta and M. Puttarudriah.	Mysore Government.
18	Mysore ..	Scheme for breeding thick canes ..	21,000	Dr. V. K. Badami and Dr. L. S. Doraiswami.	Do.
19	Coonoor ..	Visit to the Nutritional Research Laboratory.	..	(Dr. W. R. Akroyd)	....

Nos.	Places of visit.	Names of Schemes.	Sanctioned cost.	Name of the person who is doing the work.	Person or Institution in whose name the grant is made.
			Rs.		
20	Coimbatore ..	(1) Research on the genetics of sugar cane.	37,4000	Miss E. K. Janaki Ammal ..	Government of India.
		(2) Chemistry of Malting Cholam ..	11,660	Mr. Surya Narayanan	Madras Government.
		*(3) Sugar cane Scheme, Madras ..	1,50,100	Mr. Kanti Raj, Mr. S. S. Patrudu Garu.	Do.
		*(4) Dry Farming Scheme, Madras ..	1,39,510	Dr. Subba Rao, Mr. C. Vijayaraghacharya.	Do.
		*(5) Fruit Research Scheme, Madras ..	66,064	Mr. K. C. Naik	Do.
		*(6) Potato breeding Scheme, Madras..	19,995	Mr. D. G. Munro and V. Subramania Mudaliar.	Do.
21	Trivandrum ..	(1) Root disease of coconuts (Travancore scheme).	25,500	Mr. M. K. Varghese. (The scheme was recently started). (Mycologist.)	Travancore Government.
22	Hyderabad ..	Improvement of castor crop ..	61,050	A. B. H. Khurshid—Economic Botanist.	Hyderabad Government.

		Agricultural College—			
		(1) Gangai pest of rice	5,924	R. S. D. V. Bal	Central Provinces Government.
		(2) Sunn Hemp Scheme	10,660		
		(3) Oilseeds scheme	52,280		
24	Raipur ..	Rice Research Scheme, C. P. ..	91,927	Mr. B. B. Dave (Botanist) .. R. S. D. V. Bal (Chemist) ..	
25	Allahabad ..	Professor Dhar's Scheme on Nitrogen fixation.	9,360	Professor Dhar and Assistants ..	United Provinces Government.
26	Calcutta ..	(1) Professor J. N. Mukherjee's scheme on the properties of colloid and soil constituents.	32,910	Mr. Ram Prasad Mitra ..	Bengal Government.
		(2) Fruit Research Scheme ..	57,030	Mr. U. N. Vadharikar	Do.
		(3) Colonel Chopra's Scheme on medicinal plants.	62,860	Colonel Chopra and Mr. R. L. Budhawar.	Do.
		(4) Prof. Mahalanobis scheme for statistical research.	52,625	Prof. Mahalanobis and Assistants	Do.
		(5) Bengal linseed scheme ..	20,880	....	....
27	Bankura and Chinsura.	Rice Research Scheme, Bengal ..	1,56,322	Dr. S. Hadayat-Ullah and Babu Mr. S. C. Chakravarty (Chinsura). Mr. N. C. Banerji (Bankura).	Bengal Government.

* These schemes were discussed with workers at Coimbatore.

Nos.	Places of visit.	Names of Schemes.	Sanctioned cost.	Name of the person who is doing the work.	Person or Institution in whose name the grant is made.
			Rs.		
28	Rohtak ..	Dry Farming Research Scheme, Punjab	1,31,430	R. S. Jai Chand Luthra (Physiology). Dr. P. E. Lander (Chemistry). L. Tehl Ram (Agricultural work).	Punjab Government.
29	Lahore ..	Dr. Bhatnagar's Schemes—			
		(1) On the effect of ions on plant growth, and	6,523	Completed Schemes	Punjab Government.
		(2) Physico-chemical properties of soils.	9,160		
		(3) Standardisation of physico-chemical single value measurements most suitable for Indian Soils by Dr. A. N. Puri.	5,250		
		(4) Investigation of electric method of hygrometry.	3,600	Prof. J. B. Seth	Do.

	Layallpur ..	(1) Sugar cane Research Scheme ..	1,33,000	Mr. Harbans Singh and Sardar Labh Singh.	Do.
		(2) Milling and baking tests of Indian Wheats.	22,300	Grant for equipment	Do.
		(3) Oilseeds scheme	36,070	Khan Sahib Ali Mohd.	Do.
		(4) Fruit Research Scheme	11,070	Dr. Girdhari Lall	Do.
		(5) Punjab Locust Research Scheme..	37,817	Khan Bahadur Afzal Hussain and Messrs. C. B. Mathur and Abdul Haq.	Do.
		(6) Malting and brewing qualities of barleys, Punjab.	6,000	....	Do.
31	Cawnpore ..	(1) Imperial Institute of Sugar Technology.	..	This is financed from general revenues.	
		(2) Improved Juice boiling bel under the direction of the Sugar Technologist.	3,440	Mr. R. C. Srivastava	Council's Scheme.
		(3) Bureau of Sugar Standards ..	32,610	Mr. R. C. Srivastava and Mr. N. C. Varma.	Do.
		(4) Scheme for research and testing station for the indigenous system of sugar and gur manufacture.	1,67,380	Mr. R. C. Srivastava	Do.
		(5) Preparation of cattle feed from molasses.	10,000	Do.	Do.
		(6) Oil Section of the Harcourt Butler Technological Institute.	90,000	Mr. D. Y. Atthawale	United Provinces Government.
		(7) Cotton Seed Crushing and Supply of decorticated cake.	10,000	....	Do.
		(8) Malting and brewing qualities of barley United Provinces.	4,650	Rai Sahib Rama Prasada Singh ..	Do.

Nos.	Places of visit.	Names of Schemes.	Sanctioned cost.	Name of the person who is doing the work.	Person or Institution in whose name the grant is made.
			Rs.		
32	Benares ..	Plant Physiology Scheme at the Benares Hindu University.	67,920	Dr. B. N. Singh and Assistants ..	U. P. Government.
33	Muzaffarpur ..	Sugar cane Research Scheme, Bihar ..	2,25,850	Mr. K. L. Khanna	Bihar Government.
34	Pusa	(1) Potato Breeding Scheme ..	40,550	Dr. B. P. Pal	Government of India.
		(2) Botanical Sub-Station	2,63,930	Mr. Bose	Do.
35	Patna	Possibilities of manufacturing sugar by *single* pan method.	6,000	Mr. D. R. Sethi	Bihar Government.
36	Sabour ..	(1) Rice Research Scheme, Bihar ..	2,02,140	Mr. Mahbub Alam and Mr. A. R. Akhtar.	Do.
		(2) Sunn Hemp Scheme	1,440	Dr. T. C. N. Singh	Do.
		(3) Fruit Research Scheme—United Provinces an Bihar.	89,990	Mr. Zarbakht Khan and Miss Rajul Shah.	Do.
		(4) Malting and brewing qualities of barleys, Bihar.	6,000	Mr. T. C. N. Singh	Do.
37	Mungpoo ..	Cinchona investigations	..	....	..
38	Jorhat ..	Extension of *sugar cane* work at Jorhat Experimental Station.	63,000	Dr. S. K. Mitra and Mr. Phookan (Chemical Assistant).	Assam Government.
39	Shillong ..	Deep Water Paddy Scheme for Assam, at Habiganj.	1,17,882	Mr. S. Majid	Do.

40	Dacca	(1) Sugarcane Seedling Testing Station, Dacca.	24,850	Babu Gosto Behari Paul ..	Bengal Government.
		(2) Extraction of flax fibre	5,000	Rai Sahib N. C. Basu ..	Do.
		(3) Research on the Mechanical Analysis of *lateritic* soils under Prof. Ghosh (Dacca University).	71,479	Mr. A. T. Sen	Do.
		(4) Research on the organic constituents of Indian soils under Prof. Ghosh (Dacca University).	11,200	Dr. S. S. G. Sarkar and Dr. A. C. Bose.	Do.
		(5) Soil Problems in Bengal ..	22,570	Mr. M. N. Chakladar under the Agricultural Chemist, Bengal.	Do.
41	Cuttack ..	Rice Research Scheme, Berhampur ..	1,15,660	Mr. Dixit	Madras Government.
42	Simla	(1) Scheme for breeding rust resistance wheats.	..	Dr. B. P. Pal and Mr. Aziz ..	(This scheme *forms part* of Dr. Mehta's Scheme.)
		(2) Potato breeding Scheme ..	40,550	Mr. Pushkar Nath	Government of India.

H30ICAR—2,000—4-10-37—GIPS